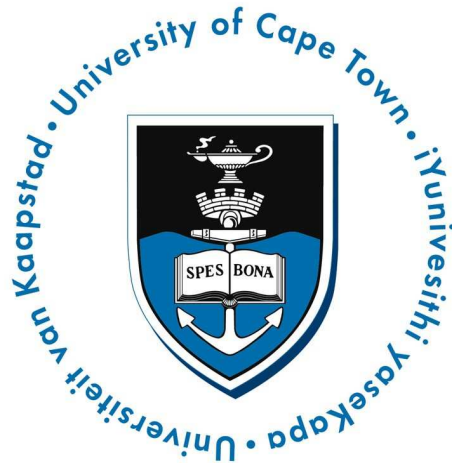


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Risks and Returns in the Globalised South African Equity Market

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ABSTRACT

The South African financial economics literature has produced many findings regarding the drivers of South African equity returns. In contrast, this thesis investigates the behaviour of South African risks and returns directly, as well as their fundamental relationship to each other (the central risk-return principle). As the Johannesburg Securities Exchange (JSE) is integrated with the international equity market, there is also a significant globalised aspect to these South African risks and returns which must be examined.

In keeping with the experience of other equity markets, a literature has developed that implies that the JSE is not, by certain measures, an efficient market. However, as with the international findings these South African EMH anomalies fail to show that investors using them can consistently make excess risk-adjusted returns on the JSE over sustained periods of time. As such, the continued use of the EMH as the base mechanism of the South African equity market cannot, to date, be rejected. Indeed, there is reason to believe that the evidence of EMH anomalies in South Africa must be treated with even more caution than must the international evidence. Of more immediate concern to this thesis, from an econometric perspective, domestic equities are found to be weak form efficient over the period under review, having no significant degrees of persistence or memory. As such, South African equities can be modeled econometrically using the standard random walk with upward drift specification widely employed in the international financial economics literature.

In contrast, domestic equity risks, defined as the variance of the returns, are found to exhibit significant degrees of persistence. The GARCH, TARCH, EGARCH and CARMA specifications were found to sufficiently accommodate this persistence of volatility on the JSE. As such, for purely parsimonious reasons it is judged that the GARCH(1,1) model provides the best specification for modeling volatility on the JSE. The leverage effect, whereby the variance following an asset price decline is higher than the variance following an asset price increase of the same magnitude, is also found to exist amongst South African equities. However, the accommodation of this effect is viewed as being desirable but not

required, as models that do not address this asymmetry accommodate domestic volatility just as well as ones that do.

The forward looking nature of equity investing requires accurate forecasts of both risks and returns. Evidence of weak market efficiency amongst domestic returns implies that it is impossible to forecast domestic financial returns. As such, the best forecast of tomorrow's equity return is an expected value of zero. In sharp contrast, the evidence of persistence implies that tomorrow's volatility can, to an extent, be forecasted according to historical price movements. This thesis finds that for a forecast of volatility one day ahead a TARCH(2,2) model is the most accurate, and for a one week ahead forecast an EGARCH(1,1) forecast is preferred. A qualification is that while most of the one day ahead forecasts are unlikely to systematically over- or under- predict volatility, the one week ahead forecasts are likely to have a systematic downward bias. In all cases, the forecasts are never able to forecast more than half the volatility, and usually far less than that, especially for a one day ahead forecast. The South African equity market typically over-forecasts forecasts, and the use of standard econometric or statistical methods could provide a better guide. A forecast using a five day moving average provides a reasonable guide to the future, at least for a one day ahead forecast. Indeed, this MA forecast appears to be better than the market in forecasting volatility on the JSE.

Significant evidence is established of a positive relationship between foreign returns and domestic returns and, in addition, between foreign volatility and domestic volatility. It is found that, for most sectors, the main association period is during the same concurrent trading day, although there are additional significant lags present in most of the series. This foreign aspect contributes approximately a fifth of the domestic market behaviour. There is substantial heterogeneity of the importance and effects of this foreign effect across time and sectors.

By focusing on the intertemporal relationship between the domestic conditional domestic equity market premium, its conditional variance and its conditional covariance with the international equity market, the thesis finds that the domestic equity market prices in both

domestic and international diversification risk. This is in line with the globalised nature of the JSE equity market. The estimated daily price of domestic variance risk is 0,0279% for every one unit of expected domestic variance, equivalent to an effective annual return (EAR) of 7,28%. The estimated daily price of covariance risk is 0,0111% (EAR: 2,83%) for every unit of expected covariance risk. The representative domestic investor values domestic variance more than covariance risk. Evidence is found that the JSE is not perfectly integrated with the world economy, in an absolute sense. Domestic investors are rewarded for holding internationally diversified portfolios, with an internationally diversified portfolio expected to have an additional daily return of 0,0238% (EAR: 6,285%) for the same level of risk as an entirely domestic equity portfolio.

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This study began, as most things do I suppose, as something completely different. Having just submitted my Masters thesis, and having some spare time after my lecturing stint, I agreed to take on a project for a financial services firm that involved the investigation of the macroeconomic drivers of the JSE. My friend and collaborator on this project, Ross Esson, sent me an article showing the effect of US market movements on UK market movements. I'm not sure why, but this idea appealed to me, to the degree that I dropped the financial (and financed) project and put all my energy into investigating this international effect on the local domestic market. This investigation germinated into a working paper relatively quickly, and soon after as a journal article in the SAJE. This original paper now forms, with some modifications, chapter five of this thesis. And then, somehow, this diversion became my doctoral study. Admittedly, the rest of the chapters came with more interest in the scholarship than in the subject matter, and there was always more of a path and never really much of a goal. In fact, the end outcome of this study, the risks and returns in a globalised equity market, emerged as much as it drove. The result, this PhD thesis, is to me more a statement of scholarship than a body of research. And of that, and it, I am truly proud.

There are many people who have been involved in the writing of this thesis. Specifically, I would like to thank the following people who were involved in different phases of this thesis:

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to Gaby and Jean

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In the lucid words of the famous British economist Lionel Robbins, economics “*is a science which studies human behaviour as a relationship between ends and scarce means that have alternative uses*” (Robbins 1932). In modern practice, economics, as a school of thought, is chiefly concerned with the optimal allocation of scarce resources in an attempt to maximise (or minimise) some function. In the large sub-school of financial economics, the scarce resource is capital, the goal is to maximise the asset base and the optimal allocation happens chiefly through the financial markets. Due to the rivalrous nature of capital, the correct discriminant of where to allocate the capital, given the maximisation function, is obviously the rate of growth (or return) it offers. However, as the allocations inevitably occur in an environment pervaded with uncertainty, an adjustment must be made for the risks associated with every return. The resultant risk-return relationship is at the heart of financial theory and practice, with higher, more certain returns always being preferred to lower, less certain returns. Financial economics then, as a sub-school of economics, reduces to the study of the risks and returns of the competing uses of capital.

In the equity market, a major capital allocation mechanism, the return is defined by the movement in an assets price, and the risk by the variance of those returns. This perspective stretches back to Markowitz (1952) and Tobin (1958), and forms the basis of much financial theory.

In the South African equity market, the focus of this thesis, a plethora of drivers of the domestic market have been proposed by researchers. These drivers have tended to follow from the makeup of the domestic equity market. For example, the dominance of the resource and commodity sectors on the Johannesburg Securities Exchange (JSE) entails that the prices of

gold, platinum and other commodities have all been shown to be key drivers of domestic equity market behaviour.

This thesis does not seek to add to this large existing literature on the drivers of the SA equity market. In this study, it is simply acknowledged that there is some underlying Data Generating Process (DGP) that provides a specific return and volatility at a certain moment in time. Rather, the focus of this thesis returns to the heart of financial economics by focusing directly on the behaviour of South African equity market risks and returns, both by themselves and through their trade-off with each other (the central risk-return relationship).

Such a broader view of market behaviour rather than market drivers is attractive for many reasons. Firstly, while the domestic research into the drivers of South African returns is clearly valuable of and by itself, that research is ultimately focused on means and not ends. From an investors' perspective, it is the behaviour of the returns over time that is ultimately important, not what caused them. Secondly, and more importantly, such a broad view of risk and return behaviour allows for a direct focus on the trade-off between equity risks and returns in South Africa. Lastly, this focus on behaviour by itself highlights a clear shortfall in the domestic financial economics literature, for a notable aspect of SA equity market research is the severe lack of investigation into the behaviour of risks, with a clear and overwhelming focus on return behaviour (more on this below).

In addition a key characteristic of the JSE, as with almost all equity markets, is its increasing integration with the international equity market through the process of globalisation. Indeed, there is reason to believe that the effect of this globalisation is possibly larger for SA than for most countries. Its relatively first world financial sophistication coupled with a relatively small market makes the JSE an attractive place for foreign capital, which enjoys relatively few restrictions on its actions. As such, any study into the risks and returns on the JSE must involve a study of the effects of globalization on them. For example, the study of SA equity risks needs to address the tendency of the market to incorporate foreign information into domestic equity prices, with the consequent exposure to contagion risks. Conversely, the study of SA returns must acknowledge that the JSE is likely to prosper in periods of bullish international markets

as international capital flows into the domestic market. In addition, this openness allows investors (both domestic and international) to reduce some of their risk by allocating capital between SA and the international markets, fundamentally changing the risk-return relationship. The focus on this globalization on domestic risks and returns, and on the risk-return relationship, is the major focus of this study.

1.2 Study Justification

1.2.1 The Contribution of South African Equity Market Research

Many of the aspects investigated in this study have comparable international studies. Where possible, the results generated in this domestic study will be compared to these. Through this way it is hoped that the study of an additional, novel equity market such as South Africa's will contribute to a greater understanding of the risk and return behaviour and relationships in an international environment.

The JSE is uniquely positioned to provide such an understanding. It is sufficiently large, in both capitalization and listed firms, and liquid to allow for adequate, comparative investigation and the rigorous employ of advanced econometric procedures (See Table 2, below). It also has a very different composition compared to the developed and well researched market bourses of New York, London and Tokyo, with relatively greater importance of the resource and commodity sectors as opposed to the financial and service sectors. It also has the property of being both relatively small and quite open internationally, allowing for the possibility of a greater impact of the international capital flows on the SA equity market compared to many other markets. The joint properties of smallness and openness are important, as both these properties make it easier to separate and investigate international effects from domestic effects. Lastly, insights gained from an equity market at the heart of SA, the dominant economy in Africa and a significant emerging economy, cannot be under-estimated.

1.2.2 Specific Research Objectives

While the individual results of this study cannot, and should not, be read in isolation given the integrated nature of this study, the main objectives underlying this contribution are the following.

Firstly, as a basis to understanding of the international dimension to domestic risks and returns, these risks and returns must be properly investigated. This thesis will discuss the evidence regarding market efficiency amongst SA equities, and then investigate the suitability of using the weak market econometric specification for domestic returns, a specification that is standard in the international literature. For market risks, which have been traditionally under-researched in SA, the thesis will examine their persistence on the JSE and the use of ARCH specifications to adequately model them. For both risks and returns a focus will be on finding the correct specification to employ for their econometric modeling. In addition, the thesis acknowledges the forward looking nature of equity investing by investigating the forecasting of both returns and risks on the JSE

Secondly, the study hopes to isolate, quantify and examine the relationships between, on the one hand, international returns and domestic returns, and on the other hand, international risks and domestic risks. This research question has its base in the widespread belief by many, including the media and market practitioners, that at least some of the behaviour of the JSE can be explained by the international equity market. Comments such as “The JSE is higher today on the back of positive global sentiment” are often heard. The empirical basis for this international/domestic link will be another key outcome to this study.

The openness of the JSE allows investors to reduce their risks by diversifying between the domestic and the international equity market. This will allow investors to earn the same returns for lower risks, or equivalently earn higher returns for the same risk. In such a globalised equity market, investors need to be compensated for two types of risks: the standard domestic volatility risk and international covariance risk due to the international diversification property

of such open equity markets. Following the fundamental relationship in financial economics between risk and return, this study will focus on isolating, quantifying and examining the return to domestic risk and international diversification risk on the JSE. As a final outcome the study hopes to investigate whether international integration has a positive effect on the domestic equity market from an investor's perspective.

1.2.3 The Modelling of SA Equity Risks

Another key overarching contribution of this study is the econometric modeling of domestic risks. As already stated, within the initial examination of equity market risks and return behavior a clear deficit in the existing literature emerges. Almost all of the existing domestic literature focuses on the expected return, at the neglect of the expected risk. This myopic look at only one side of the domestic risk return relationship is problematic given the investment function, and addressing it is a key sub-theme of this study. Indeed, this one-sided research is not unique to South Africa, most of the empirical studies that have been undertaken in the financial economics literature have tended to focus on the behavior of the conditional mean, with very little empirical attention paid to the conditional variance (Engle 2001).

This dominant focus on the mean seems at first quite odd in the study of finance. Variance, as a measure of uncertainty, is central to both financial theory and practice. Under the Capital Asset Pricing Model (CAPM) of Sharp (1964), for example, the risk premium of a specific asset is determined by its covariance with the market benchmark. In derivative pricing the variance of the underlying asset is one of the primary determinants of the respective options' price; and the covariances and variances of various assets are vital to the construction of hedging portfolios. The dominant focus on first moments by financial econometricians is therefore quite puzzling.

A major part of the reason for such neglect both domestically and internationally was due to the lack of adequate statistical tools to correctly evaluate second moments (Engle 2001). The standard econometric tools used by financial researchers by internationally and domestically, such as the Ordinary Least Squares (OLS) or probit techniques, are primarily designed for the systematic study of conditional means (be they values or probabilities), not conditional

variances. Engle's (1982) Autoregressive Conditional Heteroskedasticity (ARCH) model, and its multiple and diverse progeny, changed this completely, rebalancing the financial econometric tool-shed. These econometric procedures, which simultaneously model the second moments of the series in addition to the estimation of the first moments, allow for the same rigorous analysis of equity risks as have been applied to equity returns. The use of these tools to investigate domestic equity risks will be an important contribution of this study to the domestic financial economics literature.

1.3 General Methodological issues

1.3.1 The Foreign Equity Market Instrument

A major aspect of this study involves the JSE and the international equity market. However, the "international equity market" is clearly and admittedly an undefined amorphous entity. There is, for instance, no discrete 'trading day' on the international equity market with set open and closing times. This lack of a discrete trading day and other definitional problems is a major problem for a study such as this that attempts to model relationships between the JSE and the international equity market on a daily basis. To address this problem the London Stock Exchange FTSE index will be used throughout this study as the instrument for the international equity market. This index was used as it satisfied two major conditions.

Firstly, to substitute for the international equity market the index used had to be a major international index that incorporates the information common to the world equity market. As a major world equity index with well-documented correlations with other major indices, the LSE clearly meets these criteria. For example, amongst many others, Hamou, Masulis and Ng (1990) find significant evidence of returns and volatilities associations between the LSE and two other major exchanges, the New York Stock Exchange (NYSE) and the Tokyo Stock Exchange (TSE). By incorporating international equity market information, the LSE acts as a proxy for the international equity market.

Secondly, and most importantly, the world market proxy had to have a relatively concurrent trading period with the JSE to ensure that the covariance and spillover terms used in the estimation contained the information from the same trading day as the JSE returns and volatilities. In this regard, the LSE is clearly the best choice, as its respective trading hours are far more concurrent with the JSE's than the other major comparable exchanges. This need for concurrent information periods is also the reason why composite "World" indices, such as the MSCI World Index, were not employed.

The trading hours of the LSE and the JSE are however not perfectly concurrent, although there is sufficient overlapping. The LSE opens trading at 9:00 GMT and closes at 15:30 GMT, while the JSE trading hours run from 7:00 GMT to 15:00 GMT (9:00 to 17:00, local time). Giving the relative time zones differences, this implies that the LSE starts trading two hours after the JSE opens, and suspends trading half an hour after the JSE closes. During Daylight Saving Time (DST), when the UK sets its clocks forward one hour, the LSE opens one hour later and ends half an hour earlier than the JSE. Daylight Savings Time for the UK begins on the last Sunday in March at 01:00 GMT, and ends at 01:00 GMT on the last Sunday in October of that year. While not ideal, this overlapping is not a significant problem in generating 'clean' correlations as the study uses daily data with the index level changes being investigated incorporating the information available for the entire previous day.

Table 1, overleaf, provides some comparative information on both exchanges.

Table 1: Comparative Characteristics of the JSE and the LSE, 31st December 2004

	JSE	LSE
Size		
Market Capitalisation ^{†††}	442,5	2 865,2
As % of GDP ^{††}	163,1	136,8
# Listed Companies (Total)	389	2 837
# Listed Companies (Domestic)	368	2 486
As % of Listed Companies (Total)	94,6	87,6
# Listed Companies (Foreign)	21	351
As % of Listed Companies (Total)	5,4	12,4
Concentration		
Market Cap. Of largest 10 Firms	39,4	40,2
Market Cap. Of largest 5 % of Firms	53,8	82,2
Liquidity		
Avg. Daily Turnover ^{††}	641,7	20 350,5
# Trading days	251	254
Turnover Velocity (%) [§]	47,2	116,6
# of Trades ^{§§}	3 911,5	53 582,9
# of Shares Traded ^{§§}	45,4	1 209,4
Avg. Value of Trades [†]	41,2	96,5
Value of Share Trading (Total) ^{†††}	161,0	5 169,0
As % of Market Capitalisation	25,4	180,4
Value of Share Trading (Domestic) ^{†††}	112,2	2 940,0
As % of Share Trading (Total) [†]	69,7	56,9
Value of Share Trading (Foreign) ^{†††}	45,4	2 228,9
As % of Share Trading (Total) [†]	30,3	43,1

Notes:

Flow values for full 2004 year; Stock values as of 31st December 2004.

[†] In Thousands of USD, converted at average exchange rate for the year.

^{††} In Millions of USD, converted at average exchange rate for the year.

^{†††} In Billions of USD, converted at average exchange rate for the year.

[‡] Domestic & Foreign % may not sum to 100, residual amount due to Investment Funds contribution.

[‡] Figures for 2003. JSE figures include foreign listed firms, LSE figures do not.

^{§§} Number of trades in Thousands/Year, value in Billions of USD converted at average exchange rate for year.

[§] Defined as (Share Turnover/Market Capitalization), calculated using monthly figures.

Source: All values taken directly from World Federation of Exchanges (2004).

As can be seen in Table 1, above, the LSE is about six and a half times the size of the JSE by market capitalisation, and has over seven times the number of listed shares. The LSE has more listed foreign firms as a percentage of total listings, though both exchanges are overwhelmingly dominated by domestic firms, with a small yet significant foreign presence. Both are quite concentrated, with the LSE slightly more so.

In terms of liquidity, although the LSE clearly dominates the JSE, both are judged to be sufficiently liquid for daily prices to adequately reflect current, relevant information. As such, data drawn from both will contain sufficient information content to allow for the application of the econometric tools used in this study.

1.3.2 Data Issues

In looking at the domestic equity market this thesis will employ the JSE/Actuaries All Share Top 40 Companies Index as the domestic equity market instrument, a dividend-free value weighted (or free-float) index adjusted for equity splits and consolidations¹.

As with all time series studies an important choice regarding the frequency grain of the data must be made. This study uses daily returns in all the estimations as it was judged that this would provide the best trade-off between data and information. Using data any finer than daily, for example by employing hourly or per minute data, would be too ‘noisy’ to accurately infer information, and is likely to be plagued by microstructure data issues, such as bid-ask bounce, thin-trading and stale prices. Coarser data, such as weekly or monthly, was judged as potentially problematic as it could exclude valuable information concerning the intimate relationships under review. Given the liquidity of the ALSI40 index the daily returns are not considered to have prohibitive microstructure problems.

Unless otherwise stated, all data used in this study was obtained from the Datastream database. All transformations and assumptions are clearly detailed for each estimation procedure throughout the study. In all cases the index levels were converted into returns in the standard way by taking the natural logarithm of the ratio of consecutive daily closing levels. The resultant return series were always found to be stationary, as would be expected for returns.

The main study period under review runs from 01/01/1996 to 31/12/2004, for a total 2 234 (SA) and 2 276 (UK) observations over the full nine years. This sample period was employed for all estimations and analysis except for the chapter on forecasting risk (chapter 4), where values for implied volatility are only available for a smaller, non-overlapping period. The reasons for using a shorter period are explained in that chapter. In addition, while it may seem superfluous to note, readers should always bear in mind that the results and insights drawn

¹ Note that the exclusion of the dividends implies some understatement of returns by this index and this should be kept in mind when viewing this thesis’s results, and that of any other study that uses this standard index. This bias is however somewhat offset through the use of nominal returns.

from this study are strictly true only for the sample period under review. Table 2, below, provides some preliminary analysis of this data².

Table 2: Data Characteristics of the LSE and JSE Equity Markets

<i>Panel A: JSE</i>										
	% [†]	Mean	Median	Max	Min	Std Dev	Skewness	Kurtosis	Jarque Bera	Unit Root [§]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Basic Ind.	1,23	0,04	0,00	11,06	-13,73	1,55	-0,11	8,96	3484,1**	-21,00**
Cyc. Cns. Gds	9,05	0,06	0,00	14,28	-11,61	1,98	0,46	7,26	1862,3**	-23,28**
Cyc. Services	2,17	0,02	0,02	6,98	-9,84	1,14	-0,96	12,24	8725,0**	-18,35**
Financials	13,53	0,04	0,00	8,45	-12,46	1,33	-0,48	12,03	8075,6**	-20,30**
Gen. Ind.	2,50	0,04	0,00	7,99	-12,72	1,32	-0,53	11,28	6833,3**	-21,26**
Inform. Tech.	0,82	0,05	0,00	26,12	-18,77	2,84	7,90	221,92	73547,0**	-20,18**
NC. Cns. Gds	5,90	0,02	0,00	11,75	-13,39	1,44	-0,21	11,20	6599,1**	-21,89**
NC. Services	7,29	0,08	0,01	21,71	-17,04	2,17	0,26	11,48	7072,6**	-21,29**
Resources	57,42	0,06	0,00	8,60	-11,19	1,59	0,06	6,77	1396,3**	-21,85**
Broad	100	0,04	0,00	7,53	-11,86	1,20	-0,61	11,21	6747,2**	-21,82**
<i>Panel B: LSE</i>										
	% [†]	Mean	Median	Max	Min	Std Dev	Skewness	Kurtosis	Jarque Bera	Unit Root [§]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Basic Ind.	6,09	0,02	0,02	3,77	-4,59	0,92	-0,29	5,75	774,3**	-18,81**
Cyc. Cns. Gds	8,50	0,02	0,00	11,17	-8,81	1,39	0,18	8,51	2987,2**	-20,84**
Cyc. Services	5,38	0,00	0,01	4,43	-6,21	0,98	-0,13	5,87	815,3**	-21,38**
Financials	29,88	0,03	0,00	6,47	-8,61	1,34	0,00	5,99	874,9**	-23,65**
Gen. Ind.	3,16	-0,00	0,00	5,95	-8,63	1,19	-0,39	7,37	1931,3**	-19,81**
Inform. Tech.	9,95	0,01	0,08	12,73	-16,12	2,17	-0,31	8,17	2657,0**	-20,79**
NC. Cns. Gds	12,45	0,02	0,00	7,85	-5,95	1,20	-0,00	6,05	913,3**	-23,89**
NC. Services	8,52	0,02	0,00	8,19	-7,54	1,81	0,23	4,85	356,3**	-23,73**
Resources	14,75	0,03	0,00	9,26	-7,19	1,49	0,07	5,45	591,9**	-23,64**
Broad	100	0,01	0,00	6,08	-5,71	1,16	-0,08	5,50	614,5**	-24,25**

Notes:

Daily data, sample period 01/01/1996 to 31/12/2004, for a total of 2 234 (SA) and 2 276 (UK) observations.

[§]ADF test conducted in levels, up to lag 4, with an intercept but no trend.

[†] % of total market capitalisation by respective sector, averaged over sample.

**Significant at the 1% level.

The first column of Table 2 gives the average sectoral compositions of both the JSE and LSE over the full period. The most significant difference concerns the dominance of Resources on the JSE (making up over 50% of the weighting) and, respectively, Financials on the LSE (making up almost a third). Note, however, that in both markets these two sectors play a relatively influential role in comparison to the other sectors. Overall, there are some significant differences between the two markets in terms of composition that must be borne in mind going forward; a concern which is addressed by this thesis when need be by conducting the analysis at both the sectoral level and the broad index level.

² The Utilities sub-index is not included in the above analysis because, for the period under review, there are no South African companies included in that specific JSE sub-index. For the LSE Utilities sub-index, the respective Table values are: 1,32 (%), 0,04 (Mean), 0,00 (Median), 4,77 (Max), -5,25 (Min), 0,97 (Std Dev), 0,03 (Skewness), 7,34 (Kurtosis), 510,75** (Jacque-Bera) and -21,93** (Unit Root).

Columns two and three of Table 2 provide some measure of the returns provided by the JSE and LSE over the period under review. The returns show quite a lot of heterogeneity, both within and between the two exchanges. In general, the JSE offers higher returns than the LSE, with the JSE's Non-Cyclical Services providing the highest average daily return at 0,08%. All of the other sectors provide positive returns, with the interesting exception of the General Industries sector in the UK. Tempering these returns, columns four, five and six provides some insight into their riskiness. While the JSE provided higher returns than the LSE in all sectors (except General Industries) those returns are far more volatile and risky. In terms of specific sub-sectors, by all of these variation measures the IT sector is the riskiest in both markets; with Basic Industries and Cyclical Services being the least risky in the UK and SA, respectively.

Column eight (*'Kurtosis'*) provides some insight into the distribution of the data. Combined with the information gleaned from the standard deviation statistics, and noting that the normal distribution has a kurtosis of three, it appears that all of the return series are non-normal. Specifically, they appear to be leptokurtic, with a return having a higher probability of being both very far away from the mean and very close to it than would be the case under a normal distribution. The Jarque-Bera test bears this out formally, where the null hypothesis of normality can be rejected at the 1% level for all of the series.

The last column of Table 2 (*'Unit Root'*) provides information on the stationarity of the data. As would be expected of a return series, the Unit Root tests can be rejected at the 1% level, allowing us to conclude that the data, for all sub-sectors on both exchanges and for the broad indexes as a whole, are stationary.

This non-normality property of the data is a salient, well-known property of financial data. There are two potential solutions to this problem that are regularly used in the literature. The first involves assuming and using a more likely distribution for the returns, such as the Student-t or Generalised Exponential Distribution (GED). Both of these distributions have been used in the volatility literature; see, amongst others, de Jong, Kemna and Kloeck (1990) for the ARCH use of the Student-t distribution, and Nelson (1989) for the use of GED. The alternative solution, and the one that this study will use throughout, is to assume a Normal Distribution and then employ Bollerslev and Wooldridge (1992) quasi-maximum likelihood (QML) covariances and standard errors to generate the efficient estimators. This procedure of

employing robust standard errors is much employed in the literature, and has the major advantage of being robust against a possible misspecification of the distribution.

1.4 Organisation of Thesis

This preliminary chapter provided the background, rationale and objectives for this thesis, and addressed the salient methodological and data issues surrounding it. The forthcoming body of the thesis is divided into two broad parts. Before the investigation of the impact globalisation has had on the South African equity market can occur an initial rigorous investigation of the behavior of domestic risk and returns is required. Specifically, the correct econometric specification for both risks and returns on the JSE needs to be established if the globalised effects are to be properly investigated. This analysis is provided by chapters 2 and 3, which focus on the modeling of returns and risks, respectively. With this done the thesis then recognizes the need for forecasts of these due to the nature of equity investing. Chapter 4 examines the forecasting of risks and returns on the JSE, with the main focus by necessity on forecasting volatility. The study then moves to the core focus of this study, with the second part of this thesis analyzing the effect the international equity market has on domestic risks and returns. This is done in chapters 5 and 6.

Chapter 5 analyses the relationship between the domestic and international equity market. It focuses on the associations between equity market returns and foreign market returns, and domestic equity market risks and international equity market risks. This chapter is therefore focused on the incorporation into the domestic market of information from the international equity market, testing for the existence and magnitude of the spillover effect.

Chapter 6 then forms the capstone chapter of this study by focusing on the domestic risk-return relationship within such an international open domestic equity market. The fundamental relationship in financial economics holds that higher risk must entail higher expected risk. The internationally open property of the JSE means that it is exposed to two specific risks, both of which must be rewarded in an efficient, risk discerning market. In addition to the risk due to

higher expected variance of the returns, the risk that the globalised JSE will lose some of its international diversification properties must also be rewarded in an efficient market. This hypothesis is the focus of chapter 6. To do so it will employ an Intertemporal Capital Asset Pricing (ICAPM) model that accommodates the spillovers terms investigated in chapter 5. This chapter will also attempt to answer the question of whether the international equity market integration of the JSE is beneficial to domestic equity investors, and to quantify that benefit/cost.

Chapter 7 provides the conclusion of the study. In it the main points and findings of the study are summarised, and information emanating from this study that is of practical relevance for financial researchers and practitioners is discussed.

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CHAPTER 2

MODELLING SA EQUITY RETURNS

2.1 Introduction

This initial chapter explores domestic equity returns, the main objective of equity investing. Given the importance of these returns, it is not surprising to note that the literature on domestic returns has been exceptionally productive, mirroring the similarly large international literature. Much of this literature can be divided imperfectly into two, with one part of the literature focusing on the drivers of domestic returns and the other part on tests of its efficiency. Given such a large body, this chapter, indeed this thesis, does not seek to add to it. Instead, the aim of this chapter is to justify the use of the standard weak market efficiency specification employed throughout the following chapters of this study. In doing so, the chapter reviews what is meant by market efficiency, discusses the international and domestic literature on market efficiency and concludes by providing the econometric justification for the thesis's weak-market return specification.

As an initial diagnostic, Figure 1, overleaf, displays the behavior of the ALSI40 index over the sample period under review.



Figure 1: ALSI40 Index Behavior, 1996 to 2004

As can be seen, the overall pattern of the ALSI40 over the sample period is of a generally increasing (though volatile) index, subject to periods of significant decreases. Note in particular that while the index value approximately doubles in value over the entire sample there are particularly sharp market declines from May to September 1998, from February to May 2000 and from June 2002 to June 2003. The JSE clearly displays the emerging market characteristics of high returns coupled with high volatility. Of importance to this chapter, from first appearances the randomness of the series suggests that domestic equity prices may well behave like a random walk series, with perhaps an upward drift. This is the discussion of the next section, followed by its formal testing.

2.2 Returns Behavior: The Efficient Market Hypothesis

Central to the much of the discussion around equity return behavior both within the academic and (to a lesser extent) the private sector is the concept of the Efficient Market Hypothesis

(EMH). This chapter will approach this discussion of domestic returns from a similar perspective.

Under this EMH a share price fully reflects all relevant information regarding the asset that is available to the market. As such, all subsequent price moves (returns) are random movements away from the previous asset price, moving only when news (which is, by definition, both unexpected and random) causes the information set held by investors regarding the future behavior of the asset to change. Under this hypothesis no investor would be able to consistently make excess, risk-adjusted profit, either by using technical analysis (employing price movement informational alone) or fundamental analysis (employing non-price movement information). The result would be a random walk series, with each movement a random deviation from the previous. Note two often forgotten aspects of this EMH definition. Firstly, it is entirely consistent with the random nature of the EMH for a certain strategy to generate above normal returns so long as the strategy cannot continue to generate these excess returns consistently over time. Secondly, it is also entirely consistent with market efficiency, indeed required, that riskier strategies should (in general) attract higher returns over time³.

Furthering this EMH definition, the literature has discerned between three types of efficiency, depending on what “relevant information” is being discussed. Specifically, the seminal paper by Fama (1970) is notable for refining the concept of market efficiency into the three different types depending on the information criterion used. These types of efficiency are the weak, semi-strong and strong versions of the EMH.

The weak-market efficiency states that it should be impossible to gauge the future direction of an equity price (i.e. future return) based on previous price behavior. This definitional essentially states that no significant persistence, or memory, should be found in the time series of equity returns. This definition naturally implies that strategies that employ historical price information, such as momentum or technical analysis, should not be able to generate above average risk adjusted returns.

³ Note that this then moves the discussion on whether these above average return generation strategies have above average risk. See, for example, the discussion below on the apparent ‘size effect’ anomaly.

At the other extreme end of the EMH interpretation, the strong-market efficiency holds that even the use of privately held information that is relevant to the future behavior of the firm would not allow for excess profit to be made. Under this view, even insiders with access to private material information (such as CEO's engaged in unannounced takeover discussions) would not be able to use this information to generate above average returns.

In the middle lies the definition of semi-strong market efficiency. Allowing for the use of a greater information set than does weak market efficiency, the semi-strong version states that it should be impossible to earn excess profits from all publicly available information. Note that this is weaker than strong EMH, which holds that it should be impossible to earn excess returns from all information, both public and private. Semi-strong efficiency is concerned with fundamental analysis, the analysis of publicly available information such as P/E ratios, book to market ratios and financial ratios in order to gauge information concerning future equity behavior.

2.3 EMH 'Anomalies'

The belief that stock markets behaved according to the EMH tended to widely held until the start of the 21st century, when multiple objections against it were raised (Malkiel 2003). These findings, which drew views that equity markets were (at least partially) predictable, came to be known as anomalies. These accumulated anomalies constitute today a large international literature that has been broadly termed 'behavioral finance', as many of the justifications for such anomalies hinged on the supposed irrational psychological behavior of investors. In addition, many of these anomalies have been found amongst the domestic literature through the replication of these international studies. However, as Malkiel (2003) explains in his review article, there is not a single anomaly that stands up to consistent scrutiny, at least not to the degree that would require the outright rejection of the EMH as the base theory for modeling equity behavior.

Consider, for instance, the well known anomaly concerning the apparent nonrandom short term behavior of asset prices, where returns tend to be correlated over a short period of time. These correlations between share prices have been found internationally by, amongst others, Lo and Mackinlay (1999) and Lo, Mamaysky and Wang (2000). Domestically, the record on short term correlations is more mixed. Some studies (Jammine and Hawkins (1974), Hadassin (1976), Gilbertson and Roux (1977), Gilbertson and Roux (1978), Brümmer and Jacobs (1981) and Bendel, vd M Smit and Hamman (1996) find evidence of short term correlations, though only the first two studies find that these relationships are strong enough to allow excess return generation. In contrast, Affleck-Graves and Money (1975) and Du Toit (1986) find no evidence at all of any general short term correlations amongst South African equities. More recent studies, Jefferis and Smith (2004) and Jefferis and Smith (2005) confirm the findings of no short term correlations, suggesting that the behavior patterns found by the older studies are likely to have disappeared as the JSE became more liquid. Overall, these findings cannot imply the outright rejection of the EMH for reasons of consistency and extent. The relations found by the literature on both domestic and international short term correlations are often tenuous, time period specific (with potential objections of data mining) and so weak that trading strategies based on them are unlikely to generate excess risk adjusted returns. Indeed, using such a short term correlation strategy on the US market has been found to result in negative returns by Odean (1999).

Another anomaly focused on short-term momentum behavior concerns the apparent under- or over-reaction to specific news events for the period immediately following the announcements. Desai and Jain (1997) and Ikenberry, Rankine and Stice (1996), for instance, both find evidence of *under-reaction* to information announcements. Bissoon (2006) finds a similar under-reaction to equity news announcements amongst South African equities. In contrast, Barnard and Thomas (1997) find evidence of short term *over-reaction*. Indeed, Fama (1998) observes in his survey of this literature that evidence of under- and over-reaction to the *same* event is equally common in the literature. The implication is that the actual mechanism behind these findings may not be underlying anomaly behavior but rather mere statistical chance. Further to this point, Fama (1998) also finds that these short term results are always highly sensitive to the sample period and the econometric specification used. Evidence then of a significant, exploitable stable anomaly must be rejected as these short term momentum

findings fail to produce evidence of asset behavior that allows for the consistent generation of above average risk adjusted returns.

In addition to these short-run anomalies, the literature has isolated a few long-run anomalies. There is, for example, a well known finding concerning the apparent mean reversion of returns over the long run. Amongst others DeBondt and Thaler (1985) and Jegadeesh and Titman (1993) find that past losers (poorly performed stocks) subsequently outperformed past winners (strongly performing stocks), through some reversion to mean returns by all shares. In South Africa, the same result was found by Page and Way (2002) and Robertson, Page and vd M Smit (1999). This large contrarian investment literature is based on the understanding that investors over-react to past good news (over-buy winners) and past bad news (over-sell losers), a behavior which then corrects over the long run. The lesson is that buying loser stocks and selling/avoiding winner stocks should be a long term strategy that allows for the generation of excess, risk adjusted returns. However, there are two reasons why this may not be evidence of market inefficiency. Firstly, studies that find this result statistically significant likewise fail to show that a strategy based on it leads to statistically higher returns over time (Fluck, Malkiel and Quandt 1997). Secondly, the mean reversion of these shares may have less to do with investor over-reaction than to do with the relationship between shares and *mean reverting* interest rates, a relationship that would be required for market efficiency to exist across asset classes (Malkiel 2003).

Other apparent anomalies are the famous calendar effects, such as statistically different returns for a certain month or week day. Cross (1973) and French (1980), for example, are just some of the papers to find calendar effects in the international literature. Domestically, Bhana (1985), Bhana (1994), Le Roux and vd M Smit (2001) and Davidson and Meyer (1993) find evidence of day of the week effects amongst South African equities. In addition, Bradfield (1990) finds evidence of higher returns in December but no evidence of a January effect⁴. He concludes that this December effect is too small to generate excess returns, and is likely due to lower volatility during the holiday period (Thompson and Ward, 1995). In general, in both the domestic and international literature it appears that the older papers tend to find significant calendar effects

⁴ Note that the traditional reason given for the January effect amongst US returns is the tax reducing equity sell-off by investors in December, the end of the tax year. As SA has a different tax regime, Bradfields' (1990) finding of no January effect amongst SA equities is (partly) expected.

while the more recent studies do not, implying that the calendar effect is either tenuous (with the possibility of being the result of data mining), or that the effect disappeared through market manipulation of the now publicly known pattern. Indeed, this ‘disappearing’ calendar effect is concluded by both Le Roux and vd M Smit (2001) and Davidson and Meyer (1993).

All of the ‘anomalies’ outlined above concern weak-market efficiency, and all are at least questionable in their ability to dismiss the existence of the EMH. However, while many observers would hold that the market is weak market efficient, there is an entire industry that believes (indeed, survives on the belief) that the market is semi-strong inefficient. The investment community exists largely based on the belief that the use of fundamental analysis can generate above average, risk adjusted returns. However, as with the weak market inefficiencies it is also not clear that this is the case.

Consider, for example, the value-growth investment anomaly. In this literature shares that have been divided a-priori on the basis of certain fundamentals have statistically significantly different ex-post growth rates. Typically, the literature finds that growth shares, usually defined as having high P/E or Price-to-Book (P/B)⁵ ratios, grow slower than value shares, defined as having low values of these ratios. Internationally, this effect has been found by, amongst many others, Campbell and Shiller (1998) and has been found amongst South African equities by Cubbin, Eidne, Firer and Gilbert (2006) and Auret and Sinclair (2006). However, there are two reasons why this effect may not be a violation of the EMH. Firstly, this effect is not really an anomaly if these values are acting as a proxy for risk factors that the standard CAPM fails to capture. For instance, low P/B values are likely to exist for companies under financial distress, and their subsequent higher returns are not necessarily higher than high P/B shares by a risk adjusted measure. Indeed, this is the conclusion reached by Auret and Sinclair (2006) in explaining their JSE results. Additionally, these value-growth findings have been found to be heavily inconsistent over time (Fama 1998), ruling out their ability to consistently generate above average returns.

⁵ Also known as the book-to-market ratio.

Finally, another semi-strong anomaly proposed by the literature is the so called ‘size effect’ of equity returns, which holds that the shares of smaller capitalization firms outperform the shares of larger capitalization firms over time. While this result has been found internationally (Keim (1983), Fama and French (1993)), it has as yet *not* been found amongst South African equities. Both De Villiers, Lowlings, Pettit and Affleck-Graves (1986) and Page and Palmer (1991) find no evidence of a significant South African size effect. Malkiel (2003) provides two reasons why the international size effect findings need not be a violation of the EMH. Firstly, as is usually the case, this relationship appears to be unstable over time, ruling out its ability as an excess return strategy. Secondly, and more importantly, these smaller shares should outperform larger shares in an efficient market if they are riskier.

As Malkiel (2003) concludes, perhaps the best evidence against these anomalies, and in support of the efficient market, is that professionally investors have been unable to consistently beat the broad market index return. If the market presented systematic inefficiency then asset managers, whose incentives lead them to maximizing returns (often with the market as the base benchmark), should be able to consistently outperform a passive policy of holding the broad market. Strikingly, there is a large international body of literature that says the opposite, that asset managers are unable to systematically outperform simple buy-and-hold market portfolios (Malkiel, 2003). In South Africa, Wessels and Krige (2005) show that the local asset management industry provides the same indirect evidence for market efficiency. In their study of the period 1988 to 2003, which covers a representative period of varying bull (positive returns) and bear (negative returns) markets, the broad index consistently outperformed the average return of actively managed funds on a risk-adjusted basis⁶.

2.4 The EMH Anomalies in South Africa: Additional Caution

As discussed above, the literature on South African equities mimics that of the international literature in finding many apparent EMH anomalies on the JSE. However, not only do all of the efficient market objections raised against the international anomaly literature hold true for the domestic findings, but there are reasons to suspect that these domestic anomalies suffer from

⁶ Note that it is entirely consistent with the EMH for some (but not all) funds to beat the market, even over long time periods, as this would be the case simply through statistical chance.

even greater problems than the international studies. For instance, the far smaller research field in South Africa means that many of these studies have only been found by one (or, at most, two) research papers using roughly the same sample period, leading to a lack of independent confirmation⁷. This compounds the problem of the international literature of splashy results of anomalies being more interesting to researchers than standard confirmations of the EMH. In addition, while the liquidity and size of the JSE is likely to negate issues of thin trading in general (at least for studies using more recent data), its' concentrated shareholding structure and extensive cross holdings are likely to contribute to many of the spurious cross correlations and relationships found by these studies.

Further, the rapid change of the JSE over the last fifty (or even twenty) years means that time series based on even relatively short horizons by international studies cover periods where the JSE is, in many ways, largely incomparable. The JSE today, for example, is radically different in terms of makeup and liquidity to the JSE of 1970, making time series analysis of characteristics more problematic domestically than internationally. Studies using shorter periods to address this necessarily suffer from problems of small sample bias. Indeed, when compared to the international studies, the domestic literature almost always employs far smaller sample periods, aggravating the concerns of data mining, spurious results and tenuous sample-specific findings raised against the international literature. Tests of the January effect amongst SA equities, for example, are unlikely to be convincing, as the need to obtain sufficient annual data points extends the JSE into periods where the potential isolated pattern is unlikely to convey much information about future JSE behavior.

In addition, many of these domestic anomalies may well be ignoring relevant South African specific risk factors for many of the equities. Note that for a pattern to be an anomaly in terms of the EMH theory it has to represent a predictable pattern that will allow for excess *risk-adjusted* returns. It may well be that the standard measure of the risk for a specific share (its beta) fails to (fully) capture its risk, especially in an emerging market like SA. This is similar to the objections of the size and value-growth anomalies. For instance, it is conceivable that some

⁷ Sandler and Firer (1998), in their review of the South African finance research over the period 1947-1997, identify only 15% of the 503 published finance articles as being in the areas of market efficiency, anomalies and asset pricing *combined*. In addition, they find that most of the research has been conducted by only a handful of researchers.

non-market SA specific (political) factor could add risk to a certain class of share (e.g. the gold industry or large companies) over the studies sample period, and that that risk is not captured sufficiently by beta, if at all⁸.

2.5 Modelling SA Equity Returns Conclusion

The discussion above focused on the various studies into the EMH in South Africa. The evidence, and the conclusions to draw from it, mirror what can be said of the international literature. That is, that in any market that is set by so many market players using incomplete current information to infer the future, it is entirely possible that brief pricing mistakes and short time patterns will appear from time to time. Indeed, that must be the case, for if the market *instantaneously* priced in information perfectly then there would be no profit to be made and no need for a market to exist, a point stressed by both Malkiel (2003) and Grossman and Stiglitz (1980). However, it does not appear controversial to argue that, to date, no sustained pattern has been found domestically or internationally in the literature that conclusively and consistently produces above average, risk-adjusted returns. The conclusion then is that while there may well be transient inefficiencies, the hypothesis of the JSE as an efficient market cannot be conclusively ruled out.

For this study, however, this contentious broader debate is not necessary, as the focus is entirely on the econometric modeling of return behavior one day ahead. The goal is to justify the use by this study of the standard, weak form econometric specification that is standard in the literature. As such, the econometric techniques of this study therefore concern only the weak form of market efficiency on the JSE. Indeed, it is even weaker than that, for all that is required to justify the use in this thesis of the standard econometric specification is to show that there is no relationship between the domestic returns of subsequent trading days, i.e. no short term autocorrelation. Fortunately, for recent sample periods the literature on the JSE is in unusual agreement on this the weakest measure of market efficiency, see Jefferis and Smith (2004) and Jefferis and Smith (2005).

⁸ It is possible that this explains the finding of the size effect being significant internationally but not domestically. Large SA firms, which are likely to be in politically sensitive industries such as mining, are potentially riskier in SA than they would be in another country; and as such have the same risk-return profiles as the smaller cap shares.

Specifically, under weak market efficiency markets the prices should behave according to a random walk with upward drift, i.e. a sub-martingale. The drift exists as equity investing entails some (non-zero) risk and must therefore entail some (non-zero) return. Econometrically, as the market would provide a specific return for holding equity risk and because all expected relevant information would already be priced into the current price, the expected price of the equity at time $t+1$ at time t under weak market efficiency is given by:

$$E[P_{t+1} | \Omega_t] = \alpha + P_t \quad (2.01)$$

Where $E[.]$ is the expectational operator, Ω_t denotes the information set held at time t , α is the expected return to holding the equity asset over the period t to $t+1$ and $P_{t,t+1}$ is the price of the asset at the respective times. Respecified in terms of return over the period t to $t+1$, equation (2.01) becomes:

$$E[R_{t+1} | \Omega_t] = \alpha \quad (2.02)$$

Operationally, this specification of weak-market efficiency amongst the data under review is tested by estimating the following equation:

$$R_t = \alpha + \varepsilon_t \quad (2.03)$$

Where R_t is the return from period $t-1$ to period t , α is as before the expected return to holding the equity asset over the period and ε_t is the residual excess return at time t that was unexpected. This equation is the widely used specification of equity returns in the financial literature, especially those that employ ARCH processes.

Of importance to this study, if weak-market efficiency exists the error terms, ε_i , in equation (2.03) would be uncorrelated with its past values. Stated differently, weak-market efficiency demands that the residual to equation (2.03) be white noise. If not, the SA returns over the period under review would display weak market inefficiency as (at least some) information regarding the return at time $t+1$ would be contained in previous asset returns.

This test of weak-market efficiency on the JSE was evaluated by estimating the JSE returns according to equation (2.03) and then computing the lagged correlations of the residuals. A more formal test of such correlations is given by estimating the Ljung-Box Q-Statistic on the residuals. These correlation results, testing for correlation up to 10 days (two weeks of trading), are given in Table 3 below. Note that, as this study primarily focuses on the one day ahead expected return specification, it is the one day lag which is most important, the others are generated simply for completeness⁹.

Table 3: Weak market correlation behavior of JSE returns

$R_t = \alpha + \varepsilon_t$				
Lags	Autocorrelation	Partial Autocorrelation	Q-Stat	Prob (Q-Stat)
1	-0,009	-0,009	0,0908	0,763
2	0,071	0,071	5,3482	0,069
3	0,000	0,001	5,3482	0,148
4	-0,040	-0,045	7,0252	0,135
5	-0,013	-0,014	7,2011	0,206
6	0,032	0,039	8,3084	0,216
7	-0,020	-0,017	8,7161	0,274
8	0,034	0,027	9,9643	0,268
9	0,058	0,061	13,528	0,140
10	0,022	0,022	14,038	0,171

Notes:

Daily data, sample period 01/01/1996 to 31/12/2004, for a total of 2 351 observations.

Partial Autocorrelation removes impact of correlations of intervening lags.

As can be seen in Table 3, above, there are no significant lags (correlations) amongst the residual returns, justifying the use of the popular weak market sub-martingale specification of equation (2.03). Note especially the insignificant values of the Q-statistic and the correlation measures for the one period lag, implying no relationship between the current return (at time t) and the previous days return (at time t-1) over the sample period. As such, in the chapters that follow (specifically the next two), this study will follow the lead of the financial economics literature in modeling equity returns according to the weak market specification of equation (2.03).

⁹ Note that there are many tests of market efficiency, many of which differ through the definition of what constitutes an 'efficient' and 'inefficient' market. See, for example, Campbell, Lo and MacKinlay (1997) for a discussion of the various tests, especially those of multi-period distributional independence. It is judged, however, that for the operational needs of this thesis the momentum test presented above provides sufficient justification for the weak market return specification subsequently used in later chapters.

CHAPTER 3

MODELLING SA EQUITY RISKS¹⁰

3.1 Introduction

Given the fundamental relationship between risk and return in financial economics, the equity returns outlined in the preceding chapter must be tempered with an understanding of their associated risks. The standard risk measure in equity practice, research and theory is the (expected) variance of the returns. It is not surprising why this is the standard definition of risk amongst equities. As the definition of an equity return is the movement of its market price, the expected variance of this expected return is a direct measure of future uncertainty (or risk) surrounding such an investment asset. This study will follow this understanding and employ the variance, or rather, given the forward looking nature of investing, the conditional¹¹ variance, of the returns as the measure of risk.

The use of variance as the risk measure is not perfect. Variance is a measure of uncertainty that is closely related to, but not exactly the same, as risk. Risk is always associated with an undesirable outcome, whereas variance (as a measure solely of uncertainty) could be due to a positive effect, such as an equity price increase. Additionally, the risk of an asset is also a function of the shape of the distribution, whereas variance is just a measure of the distribution's spread. Nevertheless, given its dominant and integral use in the financial theory and practice, the variance of the returns is the measure this study will use to proxy for equity risk.

¹⁰ A version of this chapter was published as a journal article in the Journal for Studies in Economics and Econometrics, April 2007, entitled "The persistence of SA equity volatility". That paper, and indirectly this chapter, benefited greatly from comments and insights from Corné van Walbeek and an anonymous referee of the journal.

¹¹ Conditional on the current time period, t , as the variance is time-variant. See discussion below.

As should be clear, a central difference SA risks and returns is the large degree of persistence of domestic volatility, which allows for very different modeling behavior when compared to the persistence-free equity returns outlined in the previous chapter. The aim of the chapter is to investigate this volatility persistence in South Africa in order to produce two key outcomes. Firstly, the chapter will employ ARCH models to estimate the degree of persistence of domestic equity volatility. Secondly, of practical use later on in this study, the chapter aims to establish which ARCH specification is preferred for modeling SA equity volatility. .

The chapter is broadly organized as follows. Following a discussion of the persistence of domestic equity volatility, the chapter will turn to the use of various ARCH process specifications to model domestic volatility, the persistence measures implied by them and the use of the ARCH LM test as a measure of the volatility fitting properties of the various ARCH models. The chapter then concludes with the empirics, discussing the persistence tests and the choice of ARCH specification in modeling domestic volatility.

As a first look at the modeling of equity risks, consider the degree of volatility clustering inherent in domestic volatility as shown by the four graphs (each covering approximately a quarter of the entire sample period) in Figure 2 overleaf, which uses absolute¹² daily returns as a indication of the volatility of the ALSI40 index.

¹² Absolute daily returns are shown here as using squared daily returns (the actual variance measure typically employed in this paper) would make the graph largely unreadable given the large size differences between squared large returns (more than 30%) and squared small returns (less than 0.01%). The effect of volatility clustering can be seen using both absolute and squared returns.

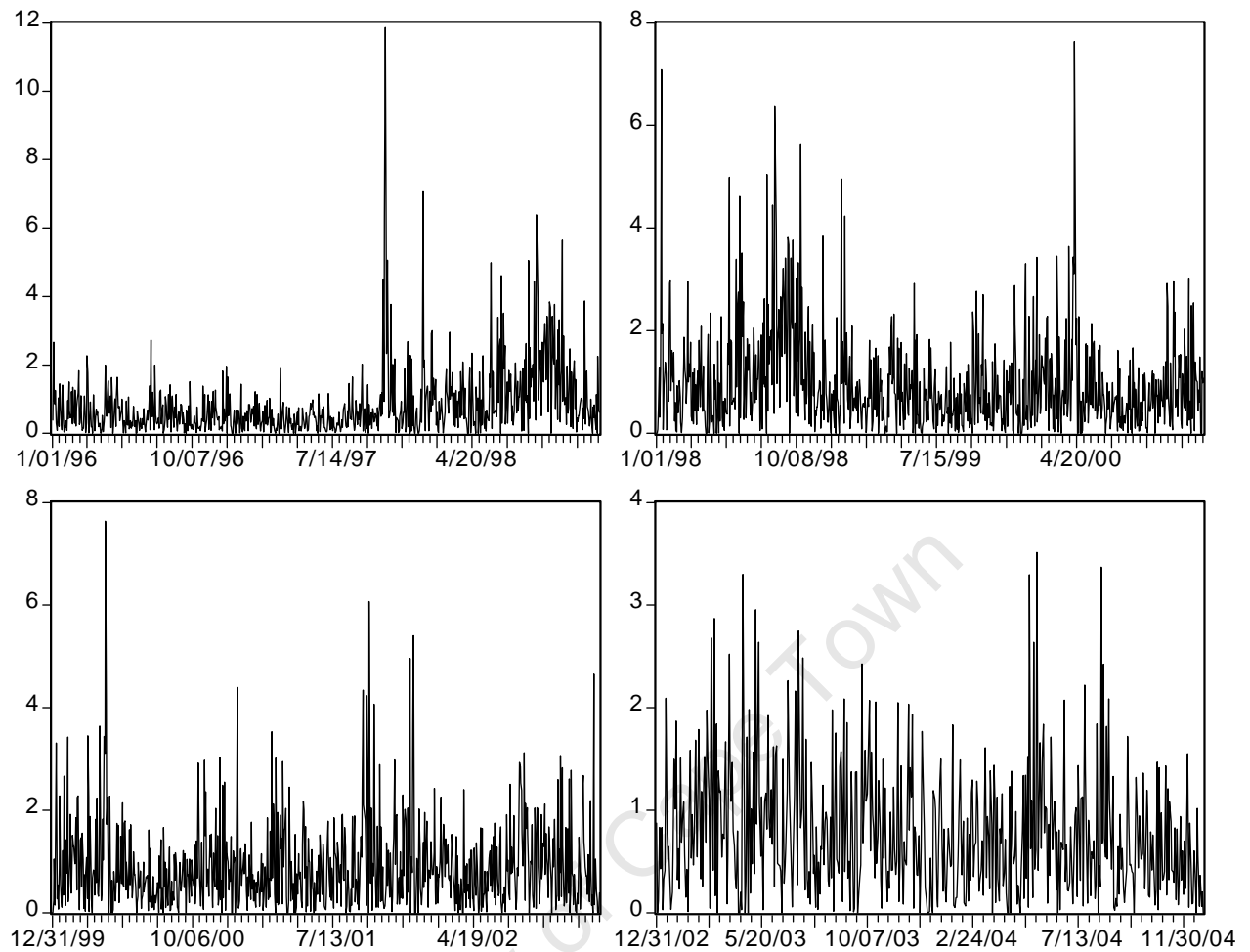


Figure 2: Clustering in ALSI40 absolute returns, 1996 to 2004

Clearly, the above series exhibits significant levels of volatility persistence; large movements are clustered with large movements, and small movements clustered with small movements. Note that this pattern excludes the direction of the return, it is the magnitudes that are following each other, not the directions. This behavior is because a large return in a certain direction is often followed by another large return of a similar magnitude, either in the same direction (herding behavior) or in the opposite direction (mean reversion behaviour or correction) as market participants endeavour to correctly price in the new information. Likewise, small returns in a certain direction tend to follow small returns of a similar magnitude, again in either direction.

Addressing this presence of volatility persistence Engle (1982) proposed estimating the conditional variance of a period based on a linear combination of past variances, a methodology he called the Autoregressive Conditional Heteroskedasticity (ARCH) model. The next section discusses this ARCH methodology in more detail, and its application to domestic equity risks.

3.2 Modelling Volatility

3.2.1 ARCH Volatility Modelling

The application of standard econometric tools by financial economists has added greatly to our understanding of finance. The employment of the standard Ordinary Least Square (OLS) model to estimate the expected value of a certain equity, for example, has provided obvious value to both the academic and private sectors alike. So too does using OLS methodology to estimate the change of a variable, such as an asset price, in response to a change in another variable, say the gold price. This OLS model, a major workhorse of applied financial econometrics, requires for its proper application that the variance of the estimated series be the same at all points. The assumption of homoskedasticity is necessary for OLS estimation to yield accurate estimations. When this assumption is violated the estimated coefficients generated from such estimations will still be unbiased, but the standard errors of the estimators are likely to be biased downwards. This condition could therefore lead to incorrect inferences regarding the statistical significance of the estimated coefficients.

Financial economists using OLS analysis soon found that this problem of heteroskedasticity was endemic in the estimation of many financial times series (Bollerslev, Chou and Kroner 1992). This empirical finding of volatility clustering was a major problem for the econometric study of financial time series. While the estimated coefficients will still be unbiased under such a scenario, the standard errors of a series with clustered volatility will be biased downwards, leading to possible incorrect inferences regarding the significance of the coefficient estimates. Engle's(1982) Autoregressive Conditional Heteroskedasticity (ARCH) model sought to

address the problem of heteroskedasticity by estimating the conditional variance of the residuals during the estimation of the condition mean of the dependent variable.

Specifically, under Engle's original Nobel Prize winning ARCH formulation the inherent volatility persistence is accounted for by combining the estimation of the conditional mean with a simultaneous estimation of the conditional variance of the unpredictable return on the equity. Specifically the variance is modeled as:

$$r_t = \alpha + \varepsilon_t \quad (3.01)$$

$$h_t = \omega + \varepsilon_{t-1}^2 \quad (3.02)$$

where the return specification follows from chapter 2 and h_t is used in the ARCH literature to denote the conditional variance for time period t.

The fundamental mechanism whereby ARCH Process models work rests on two related properties: (i) that the variance h_t in equation (3.02) is not constant in financial time series, and (ii) that there tends to be a large degree of 'memory' or persistence in such variance levels. ARCH process models therefore specify, in their most general case, the variance of the returns (risk) as a function the previous unexpected return(s). While there are many¹³ ARCH process models, in modeling South African equity volatility this thesis will employ and evaluate the widely used ARCH, Generalised ARCH (GARCH), Threshold ARCH (TARCH), Exponential GARCH (EGARCH) and Component ARCH (CARCH) specifications. These are discussed further immediately below, before being fitted to the South African equity data.

a) Symmetric ARCH Models

In modeling the conditional volatility symmetric ARCH models assume that positive and negative returns, equity price decreases and increases, affect subsequent volatility in exactly the same way. The standard symmetric specifications, and the ones that will be employed in this study, are the ARCH and GARCH models.

¹³ The naming of Figlewski's (1995) YAARCH model best illustrates the large number of ARCH models. It stands, tellingly, for Yet Another ARCH model.

i) ARCH

The first and simplest symmetric ARCH process specification is Engles' (1982) ARCH model, where the conditional variance for period t is modelled as simply being a function of some long-term mean and the square of the previous periods' excess or unexpected return:

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 \quad (3.03)$$

with ω being the time-invariant mean and ε_{t-1}^2 being the square of the excess return in equation (3.01) above. The parameters ω and α are estimated econometrically.

ii) GARCH

The standard ARCH model was generalised by Bollerslev (1986) by including the conditional variance(s) of the previous period(s) in addition to the time-invariant mean and the excess return from the previous period(s). This model, known as a Generalized ARCH (GARCH(p, q)) model, contains GARCH terms (h_{t-i}) to the lag of p and ARCH terms (ε_{t-i}) to the lag of q :

$$h_t = \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^p \beta_i h_{t-i} \quad (3.04)$$

The key advantage of this GARCH model is its ability to fit series with a large number of significant lagged effects, despite being a very parsimonious specification. This is due to two properties of the GARCH model. Firstly, the 'nesting' of an infinite amount of previous excess returns through the lagged conditional variance allows for all past equity movements to affect the conditional volatility. Secondly, the specification, through assigning declining weights to excess returns further and further into the past, accommodates the fact that more immediate returns affect volatility to a greater degree than do more distant returns.

While the specification of the GARCH(p, q) model allows for an infinite number of ARCH and GARCH lags, in practice most studies adopt low orders or 2 or less for both p and q (Bollerslev, Chou and Kroner, 1992). In this study therefore only the specifications of (1,1),

(2,1), (1,2), and (2,2) will be investigated, with the objective, as with all the variance specifications, to see which model better describes domestic equity volatility.

b) Asymmetric ARCH Models

A regular empirical finding in the ARCH equity literature is of an asymmetrical response of volatility to past returns (Bollerslev, Chou and Kroner 1992). Negative excess returns (see the excess return ε_t in equation (3.01) on p.g. 40) are often found to be followed by significantly higher volatility than positive returns of the same magnitude. The standard ARCH and GARCH specifications, in ignoring the direction of past returns, do not account for this possibly useful information. GARCH models essentially assume that good news (i.e. positive past errors) and bad news (i.e. negative past errors) of similar magnitudes affect the level of volatility to the same degree. Evidence of significant negative relationships between returns and volatility are well documented in the financial literature, with Turner, Startz and Nelson (1989), Glosten, Jagannathan and Runkle (1993), and Nelson (1991), amongst others, finding evidence of such a relationship amongst US equities.

The reason for this negative association is not widely agreed upon, with the literature providing two plausible explanations. The first view is based on a firm level financial leveraging effect. A negative return, i.e. a drop in the value of a stock, implies greater financial leverage of that firm, which makes the stock riskier and hence more volatile (Bekaert and Wu, 2000). This dominant explanation gives rise to the standard name for this negative relationship, the “leverage effect”. The second view has the causality running in the other direction. Under this view, originally associated with Pindyck (1984), markets price in volatility as a type of risk. Anticipated higher volatility on a stock raises its required return, and hence leads to an immediate negative price return.

A number of models attempt to accommodate this possible asymmetry between positive and negative returns. This study uses two well known and much employed asymmetric specifications, the TARARCH and EGARCH models.

i) TARCH

The Threshold ARCH (TARCH) model of Glosten, Jaganathan and Runkle (1993) includes a dummy variable, d_t , to distinguish negative returns from positive returns. With the inclusion of such an asymmetric effect into a standard GARCH (p,q) model, the TARCH(p,q) conditional volatility for period t is specified as:

$$h_t = \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^p \beta_i h_{t-i} + \gamma d_t \varepsilon_{t-1} \quad (3.05)$$

Where d_t is 1 if $\varepsilon_{t-1} < 0$, and 0 otherwise.

The value γ gives the extent that negative returns affect future conditional volatility by more than a positive return of the same magnitude. This chapter will investigate both a TARCH(1,1) model and a TARCH(2,2), which are the corresponding asymmetric versions of the GARCH(1,1) and GARCH(2,2) models, respectively.

ii) EGARCH

An alternative asymmetric specification is the Exponential GARCH (EGARCH) model of Nelson (1991). Here, the natural log of conditional variance of period t for ε_t is a function of the time invariable mean reversion value, ω , the natural log of past conditional variance, h_{t-1} , and both the level and absolute value of the standardised residuals, $\varepsilon_{t-1}/h_{t-1}$ and $|\varepsilon_{t-1}|/h_{t-1}$, respectively.

$$\ln h_t = \omega + \beta \ln h_{t-1} + \gamma \frac{\varepsilon_{t-1}}{h_{t-1}} + \alpha_1 \frac{|\varepsilon_{t-1}|}{h_{t-1}} \quad (3.06)$$

The inclusion of the last two terms allows the modeling of volatility to be asymmetric to past returns provided that $\gamma \neq 0$. If $\gamma > 0$, for example, then positive returns (good news/positive past errors) will have a larger effect on volatility than negative returns (bad news /negative past errors) do. The reverse would be true if $\gamma < 0$. If $\gamma = 0$ then the use of the EGARCH model would

be inappropriate; a simple GARCH model would have sufficed given the symmetry of the returns on the level of volatility.

A particular attraction of the EGARCH model over the TARCH model is that, through the interaction of the absolute and actual terms in the variance equation, the EGARCH model can determine the exact moment where the asymmetry exists. In contrast, the TARCH model sets the asymmetry at zero, i.e. only at the border between positive and negative returns. As such, in empirical terms the EGARCH specification is usually preferred over the TARCH specification for its finer modeling ability.

c) Long Memory ARCH Models

A widespread, though not universal, finding amongst the international ARCH research is the very large degree of persistence found in financial series, as implied by the estimated coefficients of the past squared returns and conditional variances (Bollerslev, Chou and Kroner 1992). The hypothesis of an approximate unit root in the volatility series can often not be rejected in many of these studies. In this case, a condition where the series is referred to as being 'Integrated in Variance' (IGARCH) (Engle and Bollerslev (1986)), the current return remains important for the forecasts of future conditional variance for all horizons, and there is no unconditional variance. While the literature identifies a few Long Memory ARCH models, this study will use the Component ARCH model, described below, to investigate the possible existence of this extended memory structure amongst SA equity volatility.

i) Component ARCH

Engle and Lee (1999) propose a useful specification of the Long Memory class of ARCH Process models. Their Component ARCH (CARCH) model allows for the separation of the influence of the past return on the conditional variance into a transitory (short run) component and a permanent (long run) component. This CARCH model proposes that the influence of past

returns on future volatility declines along two dynamics, a long-run rate of decline and a short-run rate of decline. This key distinction between permanent and temporary effects is common in the literature pertaining to unit roots in the conditional mean (Bollerslev, Chou and Kroner 1992). To understand how it does this distinction, consider the original GARCH model (equation (3.04)) with a (1,1) specification:

$$h_t = \omega + \alpha(\epsilon_{t-1}^2 - \omega) + \beta(h_{t-1} - \omega) \quad (3.07)$$

Clearly, the conditional variance of the returns here has mean reversion to some time-invariable value, ω . The influence of a past return eventually decays to zero as the volatility converges to this value ω according to the magnitude of $(\alpha + \beta)$. The standard GARCH model therefore makes no distinction between the long-run and short-run decay behavior of volatility persistence. The Component ARCH, in contrast, disaggregates the volatility by allowing for the estimation of two dynamics: a long-run time-variable component that has a mean reversion to some long-run time-invariable volatility level, and a short-run dynamic of volatility around this long-run time-variable mean volatility level. These two dynamics are known, respectively, as the permanent and transitory components.

For the permanent specification, the Component ARCH model replaces the time-invariable mean reversion value, ω , of the original GARCH formulation in equation (3.04) with a time variable component q_t :

$$q_t = \dot{\omega} + \rho(q_{t-1} - \dot{\omega}) + \phi(\epsilon_{t-1}^2 - h_{t-1}) \quad (3.08)$$

Here, q_t is the long-run time-variable volatility level, which converges to the long-run time-invariant volatility level $\dot{\omega}$ according to the magnitude of ρ . This permanent component thus describes the long-run persistence behavior of the variance. The long-run time-invariant volatility level $\dot{\omega}$ can be viewed as the long-run level of returns variance for the relevant sector

when past returns no longer influence future variance in any way. It is, in some sense, a measure of the ‘underlying’ level of variance for the respective series.

The second part of Component ARCH is the specification for the short-run dynamics, the behavior of the volatility persistence around this long-run time-variable mean, q_t :

$$h_t - q_t = \gamma(\epsilon_{t-1}^2 - q_{t-1}) + \lambda(h_{t-1} - q_{t-1}) \quad (3.09)$$

According to this transitory specification, the deviation, $(h_t - q_t)$, of the current condition variance from the long-run variance mean at time t is affected by the deviation of the previous squared return from the long term mean, $(\epsilon_{t-1}^2 - q_{t-1})$, and the previous deviation of the condition variance from the long-term mean, $(h_{t-1} - q_{t-1})$. Therefore, in keeping with its GARCH theoretical background, the Component ARCH specification continues to take account of the persistence of volatility clustering by having the conditional variance as a function of past returns. By this transitory component, the Component ARCH proposes that the influence of current volatility decays more quickly (slowly) if the magnitude of the current volatility is above (below) the long-run time-variable mean, q_t . In addition, equation (3.09) proposes that as the influence of a past return declines towards the long-run time-varying mean level of q_t its influence declines at a slower and slower rate, with the opposite happening if it is below q_t . Specifically, the influence of past squared returns of magnitudes above the time variable mean value on future volatility initially declines according to the magnitude of $(\gamma + \lambda)$, and declines according to the magnitude of (ρ) once its influence level has reached the long-run time-variable level.

Together, these two components of the CARCH model describe, just like the original GARCH formulation, how the influence of a past return on future volatility declines over time. With the CARCH model however, this persistence is separated into a short-run and long-run component, along with the estimation of the underlying variance level once the effect of both components has been removed from a series. As a tool used in the understanding and modeling of the behavior of the equity’s second moments, it is thus a major improvement on the standard

GARCH estimation. (For a graphical aid in understanding these two CARCH components, and for further discussion, see Appendix A1)

3.2.2 Persistence Decay Measures Implied From ARCH Process Modelling

The ARCH Process specifications outlined above, by explicitly modeling how the influence of past returns further and further into the past impacts on the current conditional variance, indirectly allow for a rigorous investigation of the degree of volatility persistence. This persistence modeling is easiest to see with the GARCH(1,1) formulation. Under this specification(see equation (3.04)) the rate of declining importance of a specific (squared) return, ϵ^2_{t-1} , over time can be isolated by noting the following. At time (t) the error in the squared returns is equal to the difference between the actual squared error, ϵ^2_t , and the conditional variance for that period, h_t .

$$v_t = \epsilon^2_t - h_t \quad (3.10)$$

Substituting this into the GARCH formulation in equation (3.04) and rearranging gives:

$$\epsilon^2_t = \omega + (\alpha + \beta)\epsilon^2_{t-1} + v_t - \beta v_{t-1} \quad (3.11)$$

The influence of the squared return at time (t-1), ϵ^2_{t-1} , on the current squared return at time (t), ϵ^2_t , is therefore $(\alpha + \beta)$. To isolate the effect of the squared return two periods in the past on the current squared return, we write equation (3.12) for the (t-1) period past error:

$$\epsilon^2_{t-1} = \omega + (\alpha + \beta)\epsilon^2_{t-2} + v_{t-1} - \beta v_{t-2} \quad (3.12)$$

Substituting (3.12) into (3.11) gives

$$\begin{aligned} \epsilon^2_t &= \omega + (\alpha + \beta)(\omega + (\alpha + \beta)\epsilon^2_{t-2} + v_{t-1} - \beta v_{t-2}) + v_t - \beta v_{t-1} \\ &= \omega + (\alpha + \beta)(\alpha + \beta)\epsilon^2_{t-2} + (\alpha + \beta)(\omega + v_{t-1} - \beta v_{t-2}) + v_t - \beta v_{t-1} \\ &= \omega + (\alpha + \beta)^2\epsilon^2_{t-2} + (\alpha + \beta)(\omega + v_{t-1} - \beta v_{t-2}) + v_t - \beta v_{t-1} \end{aligned} \quad (3.13)$$

The influence of the magnitude of the squared return at time (t-2), ϵ^2_{t-2} , on the magnitude of the current squared return at time (t), ϵ^2_t , is therefore $(\alpha + \beta)^2$. Note that, as the sum $(\alpha + \beta)$ is

bounded¹⁴ between 0 and 1, this return two periods in the past will have less influence than the return one period in the past.

By repeating this process through continuously recursively substituting the squared return at time (t-i), ϵ^2_{t-i} , into this GARCH specification for the squared return at time (t), ϵ^2_t , the generalised influence of the squared return ϵ^2_{t-i} on the current squared return ϵ^2_t can be isolated as being the exponential function:

$$(\epsilon^2_{t-i})_t = (\alpha + \beta)^i (\epsilon^2_{t-i}) \quad (3.14)$$

If this function is instead stated as being the isolated influence of the magnitude of the squared return at time (t) on the magnitude of the future squared return at time (t+i) then equation (3.15) becomes:

$$(\epsilon^2_t)_{t+i} = (\alpha + \beta)^i (\epsilon^2_t) \quad (3.15)$$

This exponential function (3.15) thus shows how the squared return at time t, ϵ^2_t , influences the magnitude of the future return at time (t+i) to a successively smaller and smaller degree as time progresses away from (t) by a measure (i). Specifically, its influence declines according to the linear additive $(\alpha + \beta)$ as time proceeds forward. This $(\alpha + \beta)$ amount is therefore the degree of persistence of volatility within the specific series. Where $(\alpha + \beta)$ is closer to unity, the persistence declines slowly and there is much volatility clustering as the influence of the past returns die out slowly. Conversely, there is less persistence of volatility when the sum of $(\alpha + \beta)$ is closer to 0, implying that the influence of past returns die out quickly. In the extreme case where $(\alpha + \beta)$ equals 1 the effects of the return never dies down, and when $(\alpha + \beta)$ equals 0 the return dies out immediately, i.e. there are no ARCH effects.

For the ARCH, GARCH(1,2), GARCH(2,1), GARCH(2,2), TARCH(1,1) and EGARCH models the persistence decay functions are can easily be seen as:

$$(\epsilon^2_t)_{t+i} = (\psi)^i (\epsilon^2_t) \quad (3.16)$$

¹⁴ The sum $(\alpha + \beta)$ is bounded between 0 and 1 as (i) ϵ^2_t is only covariance stationary if $\alpha + \beta < 1$ and (ii) equation (3.04) is well defined only if both α and β are non-negative (Bollerslev, Chou and Kroner 1992).

with ψ being defined as the linear summation of the all the lagged conditional variances and lagged excess returns of the variance specification. For the more complicated CARCH model, there are two persistence decay functions:

Permanent Decay Function¹⁵:

$$(q_t)_{t+i} = (\rho)^i(q_t) \quad (3.17)$$

Transient Decay Function¹⁶:

$$(h_t - q_t)_{t+i} = (\gamma + \lambda)^i(h_t - q_t) \quad (3.18)$$

¹⁵ First define the error in the squared returns at time (t) as: $v_t = \epsilon_t^2 - \sigma_t^2$, $\therefore \epsilon_t^2 = v_t + h_t$

Then the permanent decay function is given by:

$$q_t = \omega + \rho(q_{t-1} - \omega) + \phi(\epsilon_{t-1}^2 - h_{t-1})$$

Substitute in:

$$q_{t-1} = \omega + \rho(q_{t-2} - \omega) + \phi(\epsilon_{t-2}^2 - h_{t-2})$$

$$q_t = \omega + \rho(\omega + \rho(q_{t-2} - \omega) + \phi(\epsilon_{t-2}^2 - h_{t-2}) - \omega) + \phi(\epsilon_{t-1}^2 - h_{t-1})$$

$$= \omega + \rho^2(q_{t-2}) + \rho((\omega - \rho\omega + \phi(\epsilon_{t-2}^2 - h_{t-2})) - \omega) + \phi(\epsilon_{t-1}^2 - h_{t-1})$$

Which generalises to:

$$q_t = \omega + \rho^i(q_{t-i}) + f(h_{t-i+j}, q_{t-i+j}, \epsilon_{t-i+j}^2), \text{ for all } j \neq 0$$

And therefore, for the isolated influence of (q_t) at time t+i:

$$(q_t)_{t+i} = (\rho)^i(q_t)$$

The closer the estimated value of the ρ in equation (3.08) is to one the slower q_t approaches ω , and the closer it is to zero the faster it approaches ω . The value ρ therefore provides a measure of the long-run persistence. Usually, the estimated value of ρ is close to one, implying that q_t approaches ω slowly, i.e. the influence of past squared returns persist for quite some time.

¹⁶ First define the error in the squared returns at time (t) as: $v_t = \epsilon_t^2 - \sigma_t^2$, $\therefore \epsilon_t^2 = v_t + h_t$

Then the transient decay function is given by:

$$h_t - q_t = \gamma(\epsilon_{t-1}^2 - q_{t-1}) + \lambda(h_{t-1} - q_{t-1})$$

$$= \gamma\epsilon_{t-1}^2 - \gamma q_{t-1} + \lambda h_{t-1} - \lambda q_{t-1}$$

$$= \gamma v_{t-1} + \gamma h_{t-1} - \gamma q_{t-1} + \lambda h_{t-1} - \lambda q_{t-1}$$

$$= (\gamma + \lambda)(h_{t-1} - q_{t-1}) + \gamma v_{t-1}$$

Substitute in:

$$h_{t-1} - q_{t-1} = (\gamma + \lambda)(h_{t-2} - q_{t-2}) + \gamma v_{t-2}$$

$$h_t - q_t = (\gamma + \lambda)((\gamma + \lambda)(h_{t-2} - q_{t-2}) + \gamma v_{t-2}) + \gamma v_{t-1}$$

$$= (\gamma + \lambda)^2(h_{t-2} - q_{t-2}) + (\gamma + \lambda)((h_{t-2} - q_{t-2}) + \gamma v_{t-2}) + \gamma v_{t-1}$$

Which generalises for shock at time t-i on conditional variance at time (t) to:

$$h_t - q_t = (\gamma + \lambda)^i(h_{t-i} - q_{t-i}) + f(h_{t-i+j}, q_{t-i+j}, v_{t-i+j}), \text{ for all } j \neq 0$$

And therefore, for the isolated influence of $(h_t - q_t)$ at time (t+i):

$$(h_t - q_t)_{t+i} = (\gamma + \lambda)^i(h_t - q_t)$$

As the transitory component describes the relationship between the short-run and long-run influence decline rates of past return values of $(\gamma + \lambda)$ closer to unity imply slower convergence of the short-run and long-run influence decline rates, and values closer to zero the opposite. The value $(\gamma + \lambda)$ is therefore a measure of how long this non-long-run (i.e. short-run) influence rate decline. As the transitory component accounts for the possibility that the influence of past returns declines quicker (slower) if it is above (below) some long-run mean, the various half-lives given in the tables below for the transitory effects are the trading days needed for the difference between the short-run and long-run influence decline rates to decline by half. It is a function of $(\gamma + \lambda)$.

3.2.3 Half Life Measures

A relatively useful, if somewhat arbitrary, measure of the persistence behavior implied by the ARCH specifications estimations is how long it takes for a given return's influence on current conditional volatility to decline by half. This is similar to the employment of the half-life measure widely used in medical and physics research. This measure is useful as it works around the two main problems when discussing time frames of exponentially declining influence of the past squared return: (i) that it never declines completely to zero (thus making absolute lifetime estimates impossible) and (ii) that the decay slows down in an absolute sense as the returns get smaller and smaller (which makes discussions of absolute rates of decline impossible). Calculating such a half-life figure would allow not only for comparisons of the rapidity of decay in response to a return between different series, but would also provide a useful objective measure that is relatively easy to interpret.

Specifically, the formulation of equation (3.16) when the influence of the original return has declined by half is given by:

$$0.5(\epsilon^2_t) = (\psi)^i(\epsilon^2_t) \quad (3.19)$$

with ψ being defined as before as the linear summation of the all the lagged conditional variances and lagged returns of the variance specification.

Taking Logs and solving for i gives:

$$i_{HL}(\psi) = \ln(0.5) / \ln(\psi) \quad (3.20)$$

This time measure $i_{HL}(\psi)$ therefore gives the time needed, from time (t), for the effect of the original return on current volatility to decline by half. It will be this measure that this chapter uses to discuss the degree of volatility persistence within a series¹⁷.

¹⁷ To clarify for the Component ARCH, the permanent Half-life is given by
 $i_{HL}(\rho) = \ln(0.5) / \ln(\rho)$
and the Transient Half Life by
 $i_{HL}(\gamma + \lambda) = \ln(0.5) / \ln(\gamma + \lambda)$

3.2.4 The ARCH LM Test

As previously stated, a key outcome of this chapter will be information regarding the preferred ARCH model to use in modeling domestic variance. To achieve this, the study employs the ARCH Lagrange Multiplier (ARCH LM) test to evaluate the ability of the various ARCH specifications to accommodate the volatility clustering (ARCH effects). The ARCH LM test is given by:

$$\varepsilon_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 \varepsilon_{t-2}^2 + \beta_3 \varepsilon_{t-3}^2 + \dots + \beta_q \varepsilon_{t-q}^2 + v_t \quad (3.21)$$

The ARCH LM tests therefore tests the null hypothesis of no ARCH effects (i.e. no volatility persistence) up to lag length q in the residuals of the estimated equation. For a satisfactory modeling of domestic volatility persistence the respective ARCH specification would have to have an insignificant F-statistic on the ARCH LM test. For implementation purposes this study tested for significant ARCH effects up to lag 20, corresponding to one month of trading days. It was found that different lag specifications made no material change to the conclusions drawn from this evaluation. As an initial finding, the estimation of the domestic equity returns according to equation 3.01 with no ARCH variance specification generates the highly significant test statistic of 22.088. It can therefore be safely formally inferred that domestic equities exhibit a large degree of persistence, and it is this property that the ARCH models seek to accommodate.

3.3 ARCH Modelling Results

Tables 4, 5 and 4, below, give the in-sample estimated ARCH process coefficients for domestic equities (the ALSI40 index) according to the various volatility specifications given in section 3.2, along with the associated Half-lives and ARCH-LM F-Statistics. Operationally, the estimates of these values were found by estimating the equity return model of chapter 2:

$$r_t = \alpha + \varepsilon_t \quad (3.22)$$

Where r_t is the daily return for period t , defined as the natural logarithm of the ratio of the closing level of the index of day (t) on day $(t-1)$. The excess return component of the sampled returns has the distribution:

$$\varepsilon_t \sim (0, h_t) \quad (3.23)$$

With h_t being specified according to the respective ARCH model outlined above. The results, which cover the period 01/01/1996 to 31/12/2004, are given below.

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Table 4: In-Sample ALSI40 Model Parameters for Symmetric Volatility Specifications

$$R_t = \alpha + \varepsilon_t$$

$$\varepsilon_t \sim N(0, h_t)$$

$$h_t = \omega + \beta_1 \varepsilon_{t-1}^2 + \beta_2 h_{t-1} + \beta_3 \varepsilon_{t-2}^2 + \beta_4 h_{t-2}$$

Model	Parameters					ARCH-LM	Half Lives
	ω	β_1	β_2	β_3	β_4	$Lag_{(20)}$	(Days)
ARCH	1,0915** (0,0717)	0,2134** (0,0554)	-	-	-	7,5016**	0.448
GARCH(1,1)	0,0349** (0,0090)	0,1144** (0,0232)	0,8663** (0,0228)	-	-	0,7832	35.88
GARCH(2,1)	0,0345** (0,0156)	0,1154** (0,0547)	0,8347* (0,5100)	-	0,0309 (0,4555)	0,8161	36.49
GARCH(1,2)	0,0302** (0,0098)	0,1182** (0,0548)	0,8780** (0,0269)	-0,0127 (0,0594)	-	0,8870	41.93
GARCH(2,2)	0,0760** (0,0176)	0,1098** (0,0263)	-0,1102** (0,0337)	0,1250** (0,0246)	0,8325** (0,0360)	0,8417	15.85

Notes:

Daily data, sample period 01/01/1996 to 31/12/2004, for a total of 2 351 observations.

A dash (-) denotes that the parameter was not included in the specific regression estimation.

Bollerslev and Wooldridge Robust Standard Errors in Brackets.

**Significant at the 5% level

* Significant at the 10% level

Table 5: In-Sample ALSI40 Model Parameters for Asymmetric Volatility Specifications

$$R_t = \alpha + \varepsilon_t$$

$$\varepsilon_t \sim N(0, h_t)$$

$$TARCH: h_t = \omega + \beta_1 \varepsilon_{t-1}^2 + \beta_2 h_{t-1} + \beta_3 \varepsilon_{t-2}^2 + \beta_4 h_{t-2} + \beta_5 d_{t-1} \varepsilon_{t-1}^2$$

$$EGARCH: \ln h_t = \varpi_1 + \beta_2 \ln h_{t-1} + \beta_4 \ln h_{t-2} + \gamma_1 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \alpha_1 \frac{|\varepsilon_{t-1}|}{\sigma_{t-1}} + \gamma_2 \frac{\varepsilon_{t-2}}{\sigma_{t-2}} + \alpha_2 \frac{|\varepsilon_{t-2}|}{\sigma_{t-2}}$$

where d_{t-1} is 1 if $\varepsilon_{t-1} < 0$, and 0 otherwise

Model	Parameters										ARCH-LM Lag ₍₂₀₎	Half Lives (Days)
	Ω	β_1	β_2	β_3	β_4	β_5	γ_1	α_1	γ_2	α_2		
TARCH(1,1)	0,0369** (0,0084)	0,0596** (0,0216)	0,8698** (0,0251)	-	-	0,0955** (0,0206)	-	-	-	-	0,8742	30,22
TARCH(2,2)	0,0437* (0,0267)	0,0493 (0,0418)	0,7105 (0,4521)	0,0220 (0,0615)	0,1360 (0,6302)	0,1427 (0,0528)	-	-	-	-	0,8564	25,41
EGARCH(1,1)	-0,1728** (0,0342)	-	0,9592** (0,0102)	-	-	-	-0,0746** (0,0264)	0,2365** (0,0483)	-	-	1,0917	28,51
EGARCH(2,2)	-0,3053** (0,1137)	-	0,1561 (0,5850)	-	0,7721 (0,5617)	-	-0,0650 (0,0451)	0,2483 (0,0835)	-0,0721 (0,0469)	0,1692 (0,1793)	1,111	29,66

Notes:

Daily data, sample period 01/01/1996 to 31/12/2004, for a total of 2 351 observations.

A dash (-) denotes that the parameter was not included in the specific regression estimation.

Bollerslev and Wooldridge Robust Standard Errors in Brackets.

**Significant at the 5% level

* Significant at the 10% level

Table 6: In-Sample ALSI40 Model Parameters for CARCH Volatility Specification

	$R_t = \alpha + \varepsilon_t$ $\varepsilon_t \sim N(0, h_t)$ with Permanent: $q_t = \omega + \rho(q_{t-1} - \omega) + \varphi(\varepsilon_{t-1}^2 - h_{t-1})$ Transient: $h_t - q_t = \gamma(\varepsilon_{t-1}^2 - q_{t-1}) + \lambda(h_{t-1} - q_{t-1})$						
Model	Permanent Component			Transitory Component			
	ω	ρ	Half Life	γ	λ	$(\gamma + \lambda)$	Half Life
CARCH	1,454** (0,758)	0,996** (0,003)	169	0,114** (0,032)	0,770** (0,076)	0,884	5.60
							ARCH-LM Lag(20) 0,8238

Notes

Daily data, sample period 01/01/1996 to 31/12/2004, for a total of 2 351 observations.

Bollerslev and Wooldridge Robust Standard Errors in Brackets.

**Significant at the 5% level

* Significant at the 10% level

Looking at the symmetric ARCH models first, the ARCH LM tests show that the original ARCH model addresses the volatility clustering poorly. According to the test the null hypothesis of no ARCH effects can be rejected at the 5% level (actual p-value: 0,000), implying that the ALSI40 index still exhibits ARCH effects in the residuals after the ARCH model's application. The very quick decay shown by the Half-life measure of less than half a day is clearly due to the insufficient modeling of the variance series. In sharp contrast, all of the GARCH extensions show a significantly better modeling result, with the ARCH LM's null of volatility persistence accommodation unable to be rejected for all of the GARCH models. As such, all can be viewed as providing a sufficient accommodation of the South African volatility persistence. Looking at the coefficients, however, provides evidence suggesting that the GARCH(1,1) model preferable over the GARCH(1,2) and GARCH(2,1), whose additional secondary lags are not significant. In addition, according to the ARCH LM test the GARCH(1,1) model appears to address the ARCH effects just as well, if not better, than the (2,2) model, and is therefore preferable between the two for parsimonious reasons. All of the half lives are approximately equal (around 35 to 40 days), with the obvious exception of the GARCH(2,2) model. Given the results from the ARCH LM test, it is judged that the best estimate of the persistence Half-life is given by the GARCH(1,1) model, at approximately 36 days. As a final observation, note that all of the various variance equations, for the symmetric and asymmetric models, meet the necessary non-negativity and covariance stationarity conditions.

The asymmetric specifications accommodate the possibility that asset price decreases affect the subsequent conditional volatility in a different way than asset price increases of the same magnitude. As Table 5 shows, all of the asymmetric specifications provide sufficient modeling the ARCH effects according to the ARCH LM test. In addition, based on the significance of the coefficients between the two models the TARCH(1,1) appears preferable to the TARCH(2,2) model, which has many insignificant parameters. The same applies to the comparison of the EGARCH specifications, with the EGARCH(2,2) having many insignificant parameters, indicating that both types of asymmetric models potentially suffer issues of multi-collinearity. This preference for a (1,1) specification over more extensive models such as the (2,2) specification mimics the finding in the symmetric specifications.

In all the asymmetric models, price decreases are found to lead to higher variance compared to price increases of a similar magnitude. This leverage effect can clearly be seen in the significant positive value for the TARCH β_5 coefficient in Table 5, and the negative values for the $\gamma_{1,2}$ EGARCH coefficients in the same table. Note however that, following a broader pattern for the (2,2) specification, the leverage coefficients are not significantly different from zero for the TARCH(2,2) and EGARCH(2,2). Two conclusions can be drawn by this in comparison to Table 2. Firstly, focusing on the significant (1,1) specifications, the leverage effect exists amongst domestic equity risks. Secondly, the modeling of this effect does not appear to be required help in the modeling of the risks. The LM test shows both the symmetric and asymmetric specifications sufficiently address the volatility clustering of South African equities.

Table 6 provides information on the application of the Component ARCH model to domestic equity risks. All of the components are significant. For the ALSI40 index, the magnitude of the long-run ‘equilibrium’ variance level of the returns on the ALSI40 was found to be 1.45% a day. This value is the long-run level of variance of the equity returns when past returns no longer influence future variance in any way. Domestic equity volatility also has a half-life of around 169 days over the long-run. This is far lower than the corresponding half-life estimated by Engle and Lee (1999) for the US S&P index (532 days), while close to their findings on the Japanese Nikkei index (144 days).¹⁸ The values for the transitory dynamics are also highly significant. These half-lives are a measure of how many trading days it takes for the return’s rate of declining influence to revert to its long-run decline rate. The broad ALSI40 index has a short-run half-life of around 5.60 trading days, which is almost double that of the Engle and Lee (1999) result for the Nikkei (3 days) but similar to that of the S&P (5.80 days). The ARCH-LM test shows that the Component ARCH model, as with all of the other specifications excluding the simple ARCH model, provides a sufficiency accommodation of the ARCH effects.

¹⁸ It should be noted that these foreign market results are for a different, non-overlapping sample period to the one used in this paper. The US study covered the period 1941 to 1991, the Japanese study the period from 1971 to 1991 and this chapter the period 1996 to 2004.

3.4 Modelling SA Equity Risks Conclusion

This chapter found that the domestic equity risks, defined as the variance of the returns, exhibit significant persistence. This is in sharp contrast to the finding of no persistence in domestic equity returns of the previous chapter. With the obvious exception of the simple ARCH model all of the ARCH specifications were found to sufficiently accommodate this persistence. As such, for purely parsimonious reasons it is judged that the GARCH(1,1) model provides the best specification for modeling volatility on the JSE. The leverage effect, whereby the variance following an asset price decline is higher than the variance following an asset price increase of the same magnitude, is also found to exist amongst South African equities. However, the accommodation of this effect is viewed as being desirable but not required, as models that do not address this asymmetry adequately accommodate the ARCH effects amongst domestic volatilities just as well as ones that do. For the next two chapters, which both require the adequate modeling of domestic risks, the (1,1) specification will be therefore be employed, with the leverage effect being accommodated if possible. When this is leverage accommodation is done, the finer modeling ability of the EGARCH models leads to this being preferred over the TARARCH class of models.

CHAPTER 4

FORECASTING SA RISKS AND RETURNS¹⁹

4.1 Introduction

The two previous chapters discussed specific modeling aspects and properties of SA risks and returns over time. The main focus was on the correct specification to use in modeling them in the following chapters. In contrast, this chapter is more practically focused. It acknowledged that, in practice, the allocations of capital (investment decisions) are invariably forward looking. The concern of this chapter is therefore on the forecasting of equity returns and volatilities in South Africa.

Of central importance to the forecasting of any series is its degree of persistence. Highly persistent series, series where there are a large degree of momentum, are easily forecasted. Consider a simple time series where the level always increases at a known amount over time. This series is perfectly forecastable: all that is needed is the starting level and the time elapsed. In contrast, a random walk, or martingale series, is by definition not forecastable as the changes over time are random in nature.

Unfortunately, while forecasts of both risks and returns are necessary for a proper evaluation of an investment, risks and returns have very different levels of persistence in them. Chapter 2

¹⁹ A version of this chapter is to be published as a journal article in the April 2008 edition of the Investment Analysts Journal, entitled “Forecasting volatility on the JSE: The information content of ARCH processes, implied volatility and historical volatility”. That article was jointly authored with Mr Grant Shannon of Cadiz FSG, though this chapter is substantially my own work. That article, and indirectly this chapter, benefited greatly from comments and insights from Corné van Walbeek, Johann Fedderke, Martin Wittenberg, Paul Dunne, Evan Blecher, Cadiz FSG, participants on the UCT School of Economics Seminar Series and two anonymous referees from the respective journal. The help of Manoshon Pillay and Cadiz FSG in the compilation and construction of the implied market forecasts is gratefully acknowledged.

showed that JSE returns tend to have no persistence in them, while chapter 3 showed that volatility has a large degree of persistence.

It is the random walk nature of domestic equity prices discussed in chapter 2 that makes it impossible to forecast equity returns. This is not surprising, the very nature of investing ensures that it must be impossible to forecast a future return based on today's information. As such, the best forecast of tomorrow's equity price, and hence return, must be today's price plus some (very small²⁰) equilibrium risk-adjusted return. This must be true, for if profit maximizing investors expected a certain equity's price to increase tomorrow by more than the equilibrium return then it would be driven up to that price today. The expectation of the return would lead investors to buy the asset today driving up the price of the asset until the expected gain is zero, i.e. the price equals the new expected price. As such, the price will only change by more than the equilibrium return if new, relevant and unexpected information enters the market. This can be seen by looking at the correlation measures presented in Table 3 of chapter 2. The best forecast of tomorrow's return, then, based on this standard logic and the weak market efficiency test of chapter 2, is of today's price plus the (very small) equilibrium return, regardless of the past behavior of the returns.

In sharp contrast to this the previous chapter provided evidence that domestic volatility contains considerable inertia. This persistence implies that the lagged values of domestic equity volatility will provide significant information regarding the future level of volatility, and hence forecasts are indeed possible. The natural question then, and the one that this chapter attempts to answer, is which specification of volatility provides a better guide to future equity volatility.

These two different degrees of persistence between risks and returns means that the focus of this chapter will by necessity be on the forecasting of domestic equity volatility only, as returns are 'best' forecasted by the uninteresting random walk specification. Specifically, the

²⁰ Note that the daily equilibrium required return is so small that it can, and often is, taken to be zero. This would change the discussion above to the more usual statement about expecting a zero return, i.e. no price change. This difference does not change the conclusion of returns being unforecastable based on past return behaviour, especially at short horizons.

aim of this chapter is to investigate the ability of the ARCH models outlined above to forecast volatility. In addition, these ARCH process forecasts are compared to two entirely different volatility forecasts. The first forecast is the implied market forecast. Using iterative procedures, it is possible to impute the volatility priced into a derivative contract by the market. Using the new SAVI²¹ (South African Volatility Index) series of implied volatility on the TOP40 Index developed by Cadiz Securities this market forecast can be rigorously evaluated for the first time. The second alternative forecasts are based purely on historical volatility, such as a random walk (naive) or moving average forecast. These are still popular and were the dominant form of volatility forecasts before ARCH process models. Looking at the forecasting ability of these relatively simple models, in both a relative and absolute manner, will provide much insight.

4.2 The Volatility Forecasting Literature

The research into the forecasting ability of different ARCH process models is extensive, though it does tend to be overwhelmingly focused on the equity markets of a few developed countries (Poon, 2005). While the conclusions²² from this literature are very mixed, a few salient points can still be distilled from the studies on equity index volatility. Firstly, it appears that equity volatility can to some degree be forecasted. This is in sharp contrast to the forecasting literature regarding the mean, where this aspect is fiercely contested. Secondly, regarding the ability of the different ARCH process models to explain volatility: GARCH models tend to provide both superior in- and out-of-sample fit than ARCH models, while accounting for asymmetry (e.g. TARCH or EGARCH) tends to be desirable at times.

With regards to implied volatility, all but one study (Canina and Figlewski, 1993) find that it provides useful information about future volatility. Turning to the comparative forecast records approximately half (out of 39) of the ARCH process versus Implied Volatility chapters surveyed find that ARCH is better, with the other half finding that the converse. Historical models are better than Implied Volatility in 24% of the 34 papers surveyed, with

²¹ This is the approximate domestic equivalent of the CBOE's VIX, as discussed further on in this chapter in more detail.

²² This summary is based, in part, on the excellent survey of the literature chapter in Poon's (2005) book on forecasting volatility.

76% finding that Implied beats Historical. Lastly, ARCH processes outperform Implied in only one chapter, with 17 others finding the opposite is true.

The justification for this chapter is three-fold. Firstly, given the importance of volatility in the risk-return tradeoff this study hopes to provide practical information as regards to the forecast specification of the domestic equity volatility. Secondly, the comparison of the new SAVI index with the ARCH process and historical volatility models will provide information on whether the use of these models could improve the volatility forecasting ability of the domestic market. Lastly, as Bollerslev, Chou and Kroner (1992) and Engle (2001) bemoan, with few exceptions almost all of the research into volatility, including its forecasting, has used data from the US, the UK and the Japanese markets. As discussed in chapter 1, the generation of comparative SA information regarding equity volatility is a key outcome of this study.

4.3 Alternative Volatility Forecasts

4.3.1 Alternative Volatility Forecast I: Historical Volatility

While the ARCH process models construct estimates of volatility using the information provided by the mean generating process, historical volatility use the information from volatility measures directly. As such, they are far easier to construct and manipulate, which partly explains their continued use and attraction. This chapter will look at two versions of historical volatility: the naïve (random walk) forecast and the 5-day moving average. The naïve forecasts extrapolates the volatility for period t from the volatility of period $t-1$. As such, the forecasted volatility is simply the one period lagged volatility, in this case the squared excess returns. The 5-day moving average forecast, in contrast, weights the volatility (again, proxied by the squared excess returns) of the previous five days equally. Clearly, these forecasts should be secondary in forecasting power to the ARCH models, which include both a measure of mean reversion and some approximation of the volatility term structure. However, given their historical importance and so as to act as a reference base, they are generated in this study.

4.3.2 Alternative Volatility Forecast II: Implied Volatility

The two volatility models discussed thus far, ARCH process and Historical Volatility, depend on historical return data to generate volatility forecasts. There is however an alternative approach to volatility forecasting that relies on implied volatility data obtained from option prices. This implied volatility is a measure of future asset price return uncertainty over a specific time period, as priced in by the market. As such, it is usually referred to as the forward looking ‘market forecast’ of volatility. This could be a potentially better forecast than the ARCH process or Historical Volatility models as the market is likely to incorporate a far richer information set than these two inertial forecasts.

The most referenced implied volatility forecast is the Chicago Board Options Exchange (CBOE) Volatility Index, usually referred and known by its ticker symbol ‘VIX’. This volatility forecast is a daily measure of the expected volatility over the next 30 days that has priced into the S&P 500 index options. The current VIX methodology uses a strike based weighted average of option prices to calculate the implied volatility index.

The South African equivalent of the VIX is the SAVI – the South African Volatility Index, a joint collaboration between the South African Futures Exchange (SAFEX) and Cadiz Securities. This SAVI represents a daily measure of TOP40 “at the money” implied volatility over the following three months. Its calculation is such that, when compared with the current VIX formulation, it represents a lower bound for three month volatility as a whole. For further discussion regarding the construction of the SAVI, see Cadiz (2006).

The SAVI was constructed using the original methodology proposed by Whaley (2000). This approach is simpler than the CBOE (2003) formula. Adjustments are made, however, to Whaley’s method to accommodate the less liquid TOP40 option market i.e. only options within a neighbourhood of “at the money” are considered in the index construction process, where at-the-money is defined as options that are close to “at the money” for the expiry

concerned. This includes any call option with a delta²³ between 45 and 55 and any put option with a delta between -45 and -55.

On any given day the SAVI (as quoted by SAFEX) is an annualised measure of three month implied volatility. For this study, the SAVI is de-annualised by converting it into a daily volatility measure. This is done through the standard practice of dividing the annualised SAVI measure by the square root of 252, the number of trading days in a year (Poon, 2005). This daily volatility reading then generates forecasts according to the specification:

$$\hat{\sigma}_{t+1}^2 = SAVI_t^2 \quad (4.01)$$

4.4 Forecast Methodology

In addition to the JSE index data outlined chapter 1, this chapter uses the daily readings for the SAVI index provided by Cadiz FSG. This implied volatility measure is calculated from near and next-near SAFEX option data. Only at-the-money TOP40 options that display sufficient liquidity are used in the historic index construction process. More detail is provided in Cadiz (2006).

Importantly, as the SAVI is a new market instrument, being introduced to the mark only at the start of 2007, there are obviously no values for it stretching over the full sample period used by this thesis. Fortunately, however, as a promotional aid for the introduction of the SAVI index Cadiz FSG calculated its value from the start of February 2004 until the introductory presentation date of October 2007. As such, in order to incorporate the implied volatility the sample period under investigation in this volatility forecasting section runs over this reduced sample period, from 01/02/2004 to 28/09/2006, which translates into 682 actual trading days in total.

²³ Delta is the sensitivity of the options value with respect to the price of the underlying, $(\frac{\partial V}{\partial S})$.

For the ARCH process forecasts, the operational form of the mean equation estimated in this forecasting section according to the weak market specification argued in chapter 2:

$$r_t = \alpha + \varepsilon_t \quad (4.02)$$

Note that, in a significant departure from the rest of the study, the value of α , (the expected return), is imposed. This was necessary as the maximum likelihood estimation of the above equation will yield different values of α depending on the ARCH specification of the variance equation. As volatility is defined here as the movement of the returns around the mean, the value for α was defined as being the daily mean return over the sub-sample period²⁴. For the TOP40 over the sub-period under review, this is 0.0111% per day. Only in this way will an evaluation of the various ARCH process forecasts be comparing like with like.

As usual, the excess return ε_t (the excess return amount $(r_t - \alpha)$) has the distribution:

$$\varepsilon_t \sim (0, h_t) \quad (4.03)$$

and h_t being specified according to the respective ARCH process models outlined above in chapter 3. These are then used to generate the following rolling window volatility forecasts.

4.5 Rolling Window Forecasts Generation and Evaluation Methods

As this forecasting chapter seeks to evaluate how well the various specifications forecast equity volatility these forecasts are generated using rolling windows. Forecasting the future volatility using the extrapolation models that have been estimated using information across the full sample will mean that the forecast for period (t) will include information regarding the actual at (t). Forecasts generated in this fashion cannot be considered ‘forecasts’ in the true sense of the word. All of the extrapolation models’ forecasts of future volatility will therefore be out of sample forecasts, using the process of rolling estimation windows.

²⁴ Note that this then implies that a correctly specified ARCH process model will provide optimal forecasts of the squared excess daily returns $(r_t - \alpha)^2$.

These rolling estimation windows were constructed as follows. Following Blair, Poon and Taylor (2001) the forecast of volatility made at period (t) the model was estimated across the previous 100 days. Once that forecast has been made, the model is re-estimated across a sample that now includes period (t) and the previous 99 days and the forecast made at period (t+1) is generated. The process is repeated, with the model being re-estimated using a rolling window sample period of the previous 100 trading days. In this fashion, 'true' forecasts were generated for all the ARCH processes. As the historical volatility models do not include future information sets these rolling windows were not needed for the construction of their forecasts. This is arbitrarily true for the implied volatility forecast.

Two out-of-sample forecasts were generated, a one day ahead forecast and a one week (five days) ahead forecast. Following convention (Poon 2005), the volatility forecast for the one week period is taken as the sum of the individual forecasts, and evaluated against the actual daily volatility summed over those five days. In theory the forecast models should produce a better one week than a one day forecast due to the cancellation of forecast errors over the week and the mean reversion within the actual volatility. In addition, the longer forecast horizon should benefit the more complicated models as these models attempt to model the volatility term structure to a greater level than the simpler models do.

For the ARCH processes, the one week ahead forecasts were simple extrapolations of the model, with the forecasted values recursively substituted in at each step after (t). These individual forecasts were then summed to gain the respective one week ARCH process forecast. For the naïve forecast, the one day ahead was multiplied by five to get the week forecast. For the 5-day MA forecast, rolling one day ahead forecasts were generated for each of the five days, using the calculated MA forecasts for the periods after (t). These were then summed to gain the one week forecast. All of the one week forecasts then only use information available at time (t+1), ensuring that they are all 'true' forecasts.

Moving on to the evaluation of the forecast ability, whether relative or absolute, it is obviously necessary to have some criteria that compares the costs and benefits of the

forecasts. Evaluations that are based on some underlying utility function, such as that by West, Cho and Edison (1993), are not universally ideal as the shape and properties of the relevant utility function is not always known. In practice, most evaluations of competing forecasts use some measure of forecast fit that excludes any need for such utility assumptions, and simply attempts to assess the forecasts using measures based on the number, degree and direction of the forecast errors. This chapter will employ the widely used and well known measures in this non-utility based criteria school of the Mean Square Error (MSE), the Mean Absolute Error (MAE), the Root Mean Square Error (RMSE) and the Mean Error (ME). These are defined as:

$$MSE = \frac{[\sum (A_t - F_t)^2]}{n} \quad (4.04)$$

$$MAE = \frac{[\sum |A_t - F_t|]}{n} \quad (4.05)$$

$$RMSE = \sqrt{\frac{[\sum (A_t - F_t)^2]}{n}} \quad (4.06)$$

$$ME = \frac{[\sum (A_t - F_t)]}{n} \quad (4.07)$$

where A_t is the actual volatility for period (t), F_t is the forecasted volatility for period (t) and n is the number of periods over which the forecasts are evaluated. As the values of daily variance being compared are very small in an absolute sense, for purely ease of read considerations the figures are scaled up by multiplying them by 10^6 .

Of these measures, note that the ME is clearly the inferior measure as its cancelling property will lead to symmetrically inaccurate forecasts appearing as accurate predictors of the actual. The weight of interpretation should therefore always fall mainly on the other measures of fit.

In addition, the major difference between the MAE and the MSE is that the MSE penalises large deviations from the actual more heavily than does the MAE.

In addition, for forecasts to be considered ‘good’ in an absolute sense they should, at the very least, not systematically under- or over-predict the level of volatility. Formally, for a one period ahead forecast this unbiasedness requirement of relationship between the forecasted variable and the actual is written as:

$$E[A_t - F_t] | \Omega_{t-1} = 0 \quad (4.08)$$

where A_t is the actual value of the variable known at time (t), F_t is the forecast of the volatility for period t made, and Ω_{t-1} the information set available to the market at time (t-1). Operationally, the literature frequently tests the above formulation of unbiasedness of the forecasts by regressing the forecasted variable on the actual variable. This method, known as the Mincer-Zarnowitz regression, involves the estimation of the following model and the testing the joint unbiased hypothesis that $\alpha_F=0$ and $\beta_F=1$:

$$A_t = \alpha_F + \beta_F F_t + v_t \quad (4.09)$$

Where A_t and F_t are defined, as above, as is the actual volatility for period t and the forecasted future volatility for that same period t.

The results of the estimation of equation (4.02) for all the models for the sample excluding the first 100 days are given in the tables²⁵ below. Note that, due to problems of possible serial correlation in the estimation of equation (4.09), Newey-West Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors were always calculated. The tables includes the following information: the estimated coefficients for α_F and β_F , the Wald test of joint unbiasedness, the MSE, MAE, RMSE and ME figures and the adjusted Coefficient of Determination (R^2_{Adj}).

²⁵ Appendix 2 displays these various rolling volatility forecasts in a graphical format.

Table 7: Out-of-Sample Volatility Forecasts: One Day Ahead

$$\sigma_A^2 = \alpha_F + \beta_F \sigma_F^2$$

Where

σ_A^2 is the actual volatility measure, defined as Squared Excess Returns

σ_F^2 is the forecasted value of the volatility

Model	α_F	β_F	MSE	RMSE	MAE	ME	Prob (Unbiased)	R^2_{adj}
ARCH	0,000**	0,735	0,1257	0,3545	153,1133	-11,219	0,013	0,037
GARCH(1,1)	0,000	0,712	0,1158	0,3402	157,8093	12,093	0,449	0,130
GARCH(2,1)	0,000	0,683	0,1184	0,3441	161,6153	13,972	0,268	0,117
GARCH(1,2)	0,000	0,679	0,1179	0,3434	156,1390	8,307	0,351	0,115
GARCH(2,2)	0,000*	0,670*	0,1186	0,3444	157,1704	9,667	0,201	0,114
TARCH(1,1)	0,000	0,861	0,1068	0,3268	146,1898	-7,565	0,446	0,182
TARCH(2,2)	0,000	1,072	0,1042	0,3229	148,4467	-2,658	0,968	0,197
EGARCH(1,1)	0,000	1,045	0,1103	0,3321	151,1237	-6,885	0,877	0,151
EGARCH(2,2)	0,000	1,143	0,1071	0,3273	147,2120	0,550	0,672	0,142
CARCH	0,000	0,835*	0,1134	0,3368	150,9255	3,088	0,701	0,129
SAVI	0,000	0,624**	0,1189	0,3448	164,9214	25,596	0,078	0,131
Naïve	0,000**	0,236**	0,1985	0,4455	197,3536	0,152	0,000	0,054
MA(5)	0,000**	0,637**	0,1153	0,3395	153,4116	0,859	0,040	0,165

Notes:

Daily data, sample period 10/05/2004 to 28/09/2006, for a total of 682 observations.

MSE figure stated is actual MSE multiplied by 10^6 .

Prob(Unbiased) is the joint probability that $\alpha_F=0$ and $\beta_F=1$.

The SAVI measures of fit (MSE/AE/RMSE/ME and R^2_{adj}) figures are generated with $\alpha_F=0$ and $\beta_F=1$ imposed.

Significance tests are for $\alpha_F = 0$ and $\beta_F = 1$, respectively.

**Significant at the 5% level

*Significant at the 10% level

Table 8: Out-of-Sample Volatility Forecasts: One Week Ahead

$$\sigma_A^2 = \alpha + \beta_F \sigma_F^2$$

Where

σ_A^2 is the actual volatility measure, defined as Squared Excess Returns

σ_F^2 is the forecasted value of the volatility

Model	α_F	β_F	MSE	RMSE	MAE	ME	Prob (Unbiased)	R^2_{adj}
ARCH	0,000**	0,789**	1,2273	1,1078	531,1517	-48,0160	0,040	0,104
GARCH(1,1)	0,000**	0,581**	1,2101	1,1000	537,8619	77,0117	0,000	0,217
GARCH(2,1)	0,000**	0,602**	1,2174	1,1034	556,6606	91,5368	0,000	0,223
GARCH(1,2)	0,000**	0,577**	1,1797	1,0861	519,0121	61,9082	0,000	0,217
GARCH(2,2)	0,000**	0,584**	1,2039	1,0972	539,1490	76,7265	0,000	0,218
TARCH(1,1)	0,000**	0,713**	1,0651	1,0320	488,9273	-31,0063	0,000	0,251
TARCH(2,2)	0,000**	0,849	1,0158	1,0079	470,4423	-14,4262	0,094	0,253
EGARCH(1,1)	0,000*	1,316*	0,7659	0,8752	471,6773	-30,6827	0,206	0,458
EGARCH(2,2)	0,000**	1,391*	0,7816	0,8841	419,7795	4,6495	0,000	0,453
CARCH	0,000	0,937	0,8210	0,9061	416,5653	15,6420	0,919	0,389
SAVI	0,004**	0,557**	1,2554	1,1204	579,8326	135,1369	0,000	0,233
Naïve	0,000**	0,262**	2,8808	1,6973	786,3505	2,6865	0,000	0,165
MA(5)	0,000**	0,515	1,4664	1,2109	601,5678	-589,1916	0,000	0,264

Notes:

Daily data, sample period 10/05/2004 to 28/09/2006, for a total of 682 observations.

MSE figure stated is actual MSE multiplied by 10^6 .

Prob(Unbiased) is the joint probability that $\alpha_F=0$ and $\beta_F=1$

The SAVI measures of fit (MSE/AE/RMSE/ME and R^2_{adj}) figures are generated with $\alpha_F=0$ and $\beta_F=1$ imposed.

Significance tests are for $\alpha_F = 0$ and $\beta_F = 1$, respectively.

**Significant at the 5% level

*Significant at the 10% level

4.6 The One Day Ahead Forecast

From the one-day ahead results provided by Table 7, and looking at the absolute forecasting ability first, it is clear from the adjusted Coefficient of Determination that both the ARCH and naïve forecasts are very poor guides to future volatility. Despite its greater simplicity the naïve is slightly more accurate than the ARCH. The GARCH(1,1) specification provides the best forecast of all the symmetric specifications, although this is only marginal: all of the symmetric models forecast approximately 12% of the volatility. The more complex asymmetric models provide far better forecasts of volatility than the symmetric models. The TARCH forecasts outperform the EGARCH forecasts, due possibly to the short forecast horizon not providing enough room for the EGARCH specifications greater modeling of the term structure to show. Of all the asymmetric models the TARCH(2,2) is the most accurate, forecasting almost 20% of the equity volatility. Indeed, this specification provides the most

accurate one day ahead forecast of all the forecasts investigated. The Component ARCH model, for all its complexity, forecasts an unremarkable 13% of the actual, in line with the far simpler GARCH models. This may well also be a result of only looking one day ahead, as the finer structural modeling ability of the CARCH will presumably matter more at longer horizons than short horizons.

The historical volatility models have a mixed out-of-sample absolute forecasting record. The naïve forecasts are very poor, while the 5-day moving average forecasts are more accurate than all of the symmetric ARCH process models. This is a surprising result, and implies two things. Firstly, that almost all of the relevant information needed to forecast volatility on a certain day is contained in the preceding five days. Put differently, the memory structure of domestic volatility appears to be largely limited to one trading week. Secondly, information concerning the underlying (symmetric) volatility structure does not add sufficient forecasting power.

The SAVI one day ahead forecast provides a better guide to the future volatility than all of the symmetric ARCH process models, though does not outperform the asymmetric or the 5-day MA forecasts. It appears that, at least for one day ahead forecast, specific econometric (EGARCH, TARCH) and statistical (MA) forecasts can outperform the market.

The error based measures of forecast fit (MSE, RMSE, MAE, ME) provides further information supporting all of the conclusions drawn above. As higher values indicate poorer forecast records, the results drawn largely mirror that of the adjusted Coefficient of Determination. A slight difference is that the EGARCH(2,2) models performs slightly better relative to the other forecasts using these measures than it does using the R^2_{adj} , though this is minor. Note in particular the problem of using the ME measure, which (noting that lower *absolute* values imply a better fit) has the simple ARCH forecast being superior to the GARCH(2,1) forecast (-11,21 versus 13,97), contrary to all the other measures of fit. One advantageous of the ME measure is that its sign provides an (imperfect) indication of whether the volatility is over- or under-predicted by the respective model. The ME figures for the

simple ARCH specification, the TARCH(1,1), TARCH(2,2) and the EGARCH(1,1), for example, all show evidence of under-prediction, with the rest show evidence of over-prediction.

The Wald tests and coefficients values of the Mincer-Zarnowitz regression provide far better measures of this forecast bias. According to the joint Wald test of bias the simple ARCH specification and both of the historical volatility forecasts (naïve and MA) are biased. Interestingly, and of relevance to domestic market participants, the tests indicate that the SAVI market forecast is also possibly (at the 10% level) biased. The actual coefficients, especially the beta coefficients, show the bias in better detail. As estimated values greater than unity implies under forecasting (and less than unity imply over forecasting) it can be clearly seen that most of the forecasts over-predict domestic equity volatility. In the case of the naïve forecast and to some degree with the MA and SAVI forecasts, the estimate coefficients imply that this over-prediction is quite large. In contrast, the TARCH(2,2) specification (the most accurate forecast specification), the EGARCH(1,1) and the EGARCH(2,2) show evidence of slight under-prediction of volatility. These results should not be overstressed though, the formal (Joint Wald) inference tests show that only the ARCH, naïve, MA and (at the 10% level) the SAVI²⁶ have this bias as being a significant property. Overall then, in terms of forecasting volatility one day ahead the TARCH(2,2) model is preferable, though it should be borne in mind that the forecast is likely to be too low.

4.7 The One Week Ahead Forecast

As was expected, the one-week ahead forecasts presented in Table 8 were more accurate than the one-day ahead point forecasts. According to both the R^2_{Adj} and the MSE, all of the forecasts are substantially more accurate; note in particular the increased amount of volatility explained by the naïve (5,4% to 16,5%), SAVI (13,1% to 23,3%), ARCH (3,7% to 10,4%), CARCH (12,9% to 38,9%) and EGARCH(15,1/14,2% to 45,8/45,3%) specifications. In general, supporting the idea that the longer horizon allows the term structure effect to become important, the more complex models (CARCH, EGARCH) have seen the greatest increase in explanatory power. The general conclusions drawn from the one day ahead forecast regarding

²⁶ Note that the market, by its nature, is likely to overstate volatility, so this result is to a degree expected. Option writers are likely to quote higher volatility than expected to account for a profit margin and potential skewness.

the relative forecasting record are still mostly valid. Simple ARCH is the poorest ARCH process forecast (10,4%), the symmetric GARCH models have approximately the same forecasting power (21%) and the asymmetric GARCH models are more accurate than their symmetric counterparts (25,1% to 45,8%). The EGARCH (45%) and the CARCH (38,9%) models provide extremely good relative forecasts, with the forecasts more than roughly two fifths of the weekly volatility, with the EGARCH(2,2) (45,8%) explaining the most. Clearly, the longer forecast horizon provides the space for the value added of the more complicated volatility structure modeled by these specifications to play out. The MA forecast is again remarkably accurate, being a better forecast than the ARCH and GARCH models, as it was for the one day ahead forecast.

The SAVI (market) forecasts approximately a quarter (23,3%) of the volatility over the coming week. This is comparable to the symmetric GARCH (20%) models, but is definitely secondary to the asymmetric (TARCH, EGARCH) and CARCH forecasts. It appears that, as with the one day ahead forecast, econometric (TARCH, EGARCH, CARCH) and statistical (MA) techniques provides better forecasts of the volatility than does the market.

The error based measures of fit again confirm the conclusions based on the Coefficient of Determination. The EGARCH(2,2) is also judged by these measures to be the most accurate, note the difference between the MSE and MAE figures for the EGARCH(1,1) (0,765 and 471,67, respectively) and EGARCH(2,2) (0,781 and 419,77, respectively) forecasts. These imply that, though similar, the EGARCH(1,1) tends to have larger prediction errors than the EGARCH(2,2). Note the misleadingly lowest ME value (2,685) for the naïve forecast, the second poorest forecast according to the other measures.

As with the one day ahead forecast, the coefficients show there is significant evidence of over-prediction of domestic volatility by the all of the specifications, with the exception of the EGARCH models (1,1 and 2,2), which under-forecast weekly domestic volatility. The formal Wald biased tests show that only the CARCH, EGARCH(1,1) and (at the 10% level) the

TARCH(2,2) are not significantly biased, so these under and over predication properties should be noted when using these forecast specifications.

4.8 Forecasting Conclusion

The nature of financial investing is invariable forward looking. In the equity market it is necessary to have forecasts of both risks and returns. Unfortunately the very different nature of persistence in these two series leads to equity volatility being forecastable but returns not.

As stated in the introduction to this chapter, the weak market efficiency of domestic returns presented in chapter 2 implies that it impossible to forecast the random walk nature of domestic financial returns. As such, the best forecast of tomorrows equity return is an expected value of or very close to (for the small required return) zero.

In sharp contrast, the evidence of persistence presented in chapter 3 implies that tomorrow's volatility can, to an extent, be forecasted according to historical price movements. This is due to the salient volatility clustering property common to all financial assets, such as equities. The key questions then, the questions that made up the bulk of this chapter, are which historical specification forecasts are best, how good are they and how accurate does the current market forecast volatility.

This chapter found that for a forecast of volatility one day ahead a TARCH(2,2) model is the most accurate, and for a one week ahead forecast an EGARCH(1,1) forecast is preferred, though this forecast might be too low. A qualification is that while most of the one day ahead forecasts are unlikely to systematically over- or under- predict volatility, the one week ahead forecasts are likely to have a systematic bias. In all cases, the forecasts are never able to forecast more than half the volatility, and usually far less than that, especially for a one day ahead forecast.

There are two further interesting points regarding forecasting domestic volatility generated in this chapter that may be of interest to investors. The first is that the market forecasts of volatility are generally too high, and the use of standard econometric or statistical methods will provide a better guide. Secondly, and complementing the first point, a forecast using a five day moving average provides a reasonable guide to the future, at least for a one day ahead forecast. Indeed, this MA forecast appears to be better than the market in forecasting domestic volatility. The ease of construction of this forecast, especially in comparison to the more complex ARCH models, makes this an attractive finding.

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INTERNATIONAL ASPECTS OF DOMESTIC EQUITY RISKS AND RETURNS²⁷

5.1 Introduction

The previous three chapters investigated domestic equity risks and returns, looking specifically at their behavior, structure, modeling and forecasting. These are important practical areas of concern given the nature of financial economics. However, while that research into the behavior of such risks and returns in a closed environment is valuable of and by itself, the globalised nature of these returns cannot be ignored given the open nature of the domestic equity market. This international aspect of domestic risks and returns is approached in the next two chapters.

This chapter focuses in depth on the association between, on the one hand, domestic returns and international returns, and, on the other hand, domestic risks and international risks. In doing so it focuses on the direction, size and relative importance of these international risks and returns with regards to domestic price determination. The next chapter, chapter 6, then continues this study into the international dimension of the JSE by focusing on how the globalised nature of the JSE directly affects the domestic risk-return relationship.

The international association of domestic equity risks and returns is intimately connected to the open nature of the JSE. If, for example, the domestic equity market was perfectly

²⁷ A version of this chapter was published as a journal article in the South African Journal of Economics, June 2006, entitled “The relationship between international equity market behavior and the JSE”. It also appeared as an Economic Research South Africa (ERSA) working paper (WP#42) under the same name. Those papers, and indirectly this chapter, benefited greatly from comments and insights from Corné van Walbeek, Shakill Hassan, Haim Abraham, Greg Brooks, Lawrence Edwards, Phillip Black, participants in the UCT School of economics seminar series and an anonymous referee from the SAJE.

segmented from the world market there would be no significant relationship between the JSE and the international equity market. Each market would react only to domestic market conditions, with no need to impound foreign information. If, however, the domestic market were completely integrated then it would be perfectly correlated with the international market given the entirely common market conditions and information set. In reality, a global equity market such as the JSE is likely to be only partly associated with the international market, with both domestic and foreign information playing a part. It is these (common information set driven) partial associations that this chapter examines.

The literature on this type of ‘integration versus segmentation’ research is chiefly focused on to what degree markets are segmented, not if they are integrated (Guh, et al, 2004). In this literature, segmentation is defined as the deviation from a situation of ‘total financial integration’. In turn, ‘total financial integration’ is defined as a situation encompassing both direct integration, where different markets have the exact same risk-return profile, and indirect integration, where the risk-return profile in one country is indirectly linked to the risk-return profile of another country. This chapter feeds into this literature by accepting that the JSE is partly segmented, i.e. that there is no ‘total financial integration’, and then investigating the characteristics of this integration.

That the JSE’s behavior is linked (or associated) with the foreign equity market is widely held to be fact. Both the press and analysts often explain certain behavior of the JSE as being affected by the behavior of other security exchanges²⁸. The local bourse, for example, is often said to be ‘tracking’ a certain foreign bourse. Foreign indices are widely understood to affect not only the level of the JSE but also its volatility; both moments of foreign bourses are thought to cross international borders.

This chapter investigates empirically the existence and extent of this association between foreign equity markets and the JSE. Specifically, it estimates to what extent market returns and volatility on the JSE are associated with international market returns and volatility, using

²⁸ Consider the following exemplary quote: “The JSE was higher this afternoon on the back of positive global markets.” *Business Day*, 25 October, 2005

the London Stock Exchange (LSE) as a proxy for the international market. As will be explained later, the associations are tested at two specific levels, the broad market index level and the narrow sector level, in order to account for differing exchange compositions.

5.2 The Transmission Literature

The transmission literature makes quite a clear distinction between interdependence amongst markets and contagion amongst markets. The correlation of asset prices and volatility between stock exchanges is generally known as interdependence or integration. Contagion on the other hand is most commonly defined as an increase in the correlations of asset prices and volatility during a period of turmoil (Collins and Biekpe, 2003). This chapter will be testing for interdependence as it seeks to estimate the extent that domestic market returns and volatility are associated with foreign returns and volatility.

The international literature on transmissions is extensive. Amongst others, Lin, Engle and Ito (1994) find correlations between day (night) returns on the New York Stock Exchange (NYSE) and night (day) returns on the Tokyo Stock Exchange (TSE) using a GARCH methodology. Day returns are defined in their paper in the standard way as the open-close change in a respective index, and night returns defined as the close-open changes.

Barclay, Litzenberger and Warner (1990), also studying the perfectly non-overlapping markets of the TSE and the NYSE, find evidence of correlations amongst dual listed stocks. Hamou, Masulis and Ng (1990), using ARCH processes, find evidence of unidirectional transmissions of returns and volatilities from the NYSE to the TSE, from the LSE to the TSE and from the NYSE to the LSE.

Locally, studies on the interdependence of the JSE have mostly focused on its relationship with other African equity markets. Collins and Biekpe (2003), for example, investigated whether certain African economies, including South Africa, experienced contagion from the Asian Crisis in 1997. They found that the correlations between African markets and the Hong

Kong Hang Seng Index increased during the crisis period of October 20, 1997 to November 28, 1997. Piesse and Hearn (2005), using methodology adopted by this chapter, find evidence of the transmission of both returns and volatility amongst Sub-Saharan African stock markets. Piesse and Hearn (2003), testing for price volatility transmissions across SACU equity markets, found evidence of integration using cointegration analysis.

Lastly, using a vector autoregression (VAR) approach, Collins and Abrahamson (2004) investigated whether various African stock exchanges, including the JSE, are more integrated regionally than globally. While not explicitly testing for association with international equity markets, they did find that South Africa was the most globally integrated of the seven African countries investigated. The countries tested in their study were Egypt, Kenya, Mauritius, Morocco, Namibia, Zimbabwe and South Africa.

5.3 Study Justification

The key aspect of this chapter, and this study, is the detailed investigation into the international aspect of South African risks and returns. In doing so it contributes to the existing literature in two additional ways. Firstly, the chapter explicitly tests the relationship between foreign volatility and domestic volatility and not just the relationship between foreign and domestic market returns. Secondly, the chapter addresses the problem of different stock market composition by estimating the correlation between individual foreign and domestic sectors in addition to broad index level association estimations.

5.3.1 Formal testing of intra-market volatility association

Most tests of association test some form of correlation between the returns of two or more markets. This chapter does this within a framework that also formally tests whether the level of market volatility, and not just market returns, crosses borders. This is achieved by including a measure of foreign volatility up to i lags in the specification of the conditional

variance. This Factor ARCH specification will allow for the explicit test of intra-market association of both conditional moments²⁹.

5.3.2 Additional Sector-to-Sector study

A significant problem in estimating the correlations between the LSE and the JSE is that the two equity markets have very different compositions. The JSE is dominated by the mining sector, whereas the LSE is dominated by the financial and service sectors. Estimating the degree of correlation between the broad JSE index and the broad LSE index could therefore provide misleading results.

To understand why, consider two stock markets (X and Y, respectively), both of which have only two sectors, A and B. Assume that the two sub-sectors in both markets are in fact perfectly correlated, i.e. $\text{Corr}(A_X, A_Y)$, $\text{Corr}(B_X, B_Y) = 1$. Also assume that stock market X is dominated almost entirely by sector A, and stock market Y almost entirely by sector B. If specific information becomes available that causes sector B in both markets to be sold and sector A in both markets to be bought the two stock markets would move in opposite directions, even though the equity markets are in fact perfectly correlated.

In general then, testing for market correlation is strictly only true when the stock markets have exactly the same composition of sectors. This chapter attempts to address this problem by testing for contagion not only between the broad markets but between the individual sectors of the indices as well. The sectors used are the ten sectors as defined by the FTSE Global Classification System; a classification system common to both respective indices. These sector classifications are: Basic industries, Cyclical consumer goods, Cyclical services, Financials, General industrials, Information technology, Non-cyclical consumer goods, Non-cyclical services, Resources and Utilities. In practice, however, only nine of the ten series could be investigated as the Utilities sub-index of the JSE contains no companies over the sample period. Note that the sectoral level data was provided by Datastream, and as such did not need to be constructed.

²⁹ A Factor ARCH is the broad name given to any ARCH process model that has (an) additional exogenous variable(s) included in its conditional variance specification (Bollerslev, Chou & Kroner 1992).

5.4 Chapter Specific Data Issues

As always, the JSE/Actuaries All Share 40 Top Companies Index (ALSI40) was used as the measure of the broad domestic equity market, and the Financial Times-Stock Exchange 100 Share Index (FTSE 100) for the broad foreign equity market. The case for using the LSE as the international market proxy was presented in chapter 1, above. The nine sectoral indices for each market were sub-indices of each of these two respective broad indexes. The chapter used the usual data sample, consisting of the daily levels of both the broad indices and the nine individual sub-series for both indices, running over the usual sample period of 01/01/1996 to 31/12/2004.

Only two transformations of the data were necessary. The series was converted from levels into returns in the standard way by taking the natural logarithm of the ratio of consecutive daily closing levels. Secondly, and in contrast to the rest of the chapters, dummy variables were constructed for both markets to designate holidays and return periods that included the information of more than one period, i.e. the trading day following the holiday(s). This was necessary as the two different markets have different non-market days due to country specific public holidays. Addressing this ensures that only days when both markets trade concurrently are evaluated for the association tests. Extreme outliers in both series were not excluded as they are an integral part of the international market correlation analysis. For example, the information that a certain trading day has extremely large price movements in both markets is important for this association study and must be included, as is the information that an extremely large movement occurred in only one market and not the other.

Table 9, overleaf provides the summary statistics of the risks and returns on the two indices, as well as the full sample simple correlation measures. For the table, squared daily returns are used as the measure for volatility, and the natural log of the ratio of consecutive closing daily levels for the returns.

Table 9: Summary Statistics for JSE and LSE Associations

	Returns			Volatility		
	\bar{R}_{SA}	\bar{R}_{UK}	$\text{Corr}(R_{SA}, R_{UK})$	$\overline{R_{SA}^2}$	$\overline{R_{UK}^2}$	$\text{Corr}(R_{SA}^2, R_{UK}^2)$
Basic Ind.	0,0431	0,0206	0,3484	2,4303	0,8594	0,3119
Cyc. Cns. Gds	0,0212	0,0655	0,2025	3,9345	1,9528	0,0837
Cyc. Services	0,0259	0,0087	0,4328	1,3069	0,9787	0,2920
Financials	0,0400	0,0354	0,4413	1,7739	1,8030	0,2613
Gen. Ind.	0,0450	-0,0017	0,3110	1,7535	1,4186	0,1740
Inform. Tech.	0,0518	0,0140	0,3896	8,1091	1,8030	0,0430
NC Cns. Gds	0,0295	0,0235	0,2444	2,0895	1,4602	0,1319
NC Services	0,0818	0,0284	0,2721	4,7510	3,3090	0,1010
Resources	0,0620	0,0357	0,2985	2,5506	2,2320	0,1404
Broad	0,0422	0,0181	0,4483	1,4452	1,3487	0,2051

Notes:

Daily data, sample period 01/01/1996 to 31/12/2004, for a total of 2 351 observations.

R_{sa} denotes daily ALSI40 returns, R_{uk} denotes daily FTSE100 returns.

The macron ($\bar{}$) indicates an average figure.

Correlations are with same sector, i.e. Financials correlation figure is $\equiv \text{corr}(\text{SA Financials}, \text{UK Financials})$.

Looking at the equity returns first, it is clear that the broad domestic market has a higher average daily return over the period than the LSE. They are however both positive, reflecting the positive growth in these two indices over the sample period. Looking at sectoral performance, the JSE has higher returns than the LSE in all sectors excluding the Basic Industries and Cyclical Consumer Goods sectors. There is a substantial amount of heterogeneity amongst the sectors, both within the two indices and between them. Domestically, the Non Cyclical Services sector has the highest average daily return, while on the LSE it is the Cyclical Consumer Goods. The resources sector is a relatively strong performer in both markets, while Cyclical Services is a relatively poor one in both.

As an initial look at the international relationships, the individual return correlations are also mixed. That none of them are higher than 0,5 suggests that the larger part of the price determination is by country specific information. Individually, the correlations can generally be sorted into two broad groups, with the returns in the Basic Industries, Cyclical Services, Financials, and Information Technology relatively more associated internationally than the rest. The two Financials sectors are the most integrated of all by this simple measure. Also in terms of this initial measure the Cyclical Consumer Goods sector is the least associated with

its international counterpart. Finally, and interestingly, the broad indexes are relatively strongly correlated with each, more so than any individual index.

The equity risks have a similar mixed record. The domestic market is, in general, more volatile than the LSE both in the broad sector and in every sector except Financials, where they are approximately equal. The variance of the IT sector is exceptionally high in South Africa, and amongst the highest on the LSE, reflecting the nature of this sector over the sample period of mid 1990's though mid 2000's. On the LSE, the Non Cyclical Services sector is the most volatile by a significant degree. In terms of international relationships, the simple correlations show that Basic Industries, Cyclical Services and Financials are again the most internationally integrated, although the Information Sector no longer has this property. In general, equity risks are far less internationally integrated than the equity returns.

Overall then, Table 9 provides some initial evidence that there is an international dimension to at least some of the domestic returns and risks. The methodology outlines next will investigate this dimension in far more depth.

5.5 Methodology

This chapter uses the methodology of Lin, Engle and Ito (1994) to model the international association effect. In their Aggregate-Shock model, the Foreign Daily Return (on the LSE) is specified as:

$$FDR_t = \alpha_1 + \beta_1 FDR_{t-1} + \beta_2 DH + \varepsilon_t \quad (5.01)$$

where FDR is the foreign daily daytime return for period t , defined as the natural logarithm of the ratio in the closing levels of trading period t on trading period $t-1$; and DH is a vector of non-trading-day and day-after-holiday period dummies.

This peculiar specification of the foreign (LSE) return differs slightly from that used so far, and therefore requires some explanation. The Holiday/ Post Holiday dummy vector accounts for those return periods where there is no trading and for periods that incorporate the information of more than one period. This was necessary as the two different markets have different intra week non-trading days due to country specific public holidays. Addressing these two issues ensures that only days when both markets trade concurrently on a single days' information are evaluated for the association tests. The specification also allows for the potential autocorrelation of the Day returns with the previous Day returns (return persistence). Even though this effect was shown to be insignificant in chapter 2, it was included here as an additional precaution in order to further absorb domestically produced return information. This will further aid in the isolation and separation of foreign effects from domestic effects, and is more important for the domestic return specification (given below). It is included here for symmetric modeling reasons. The return not accounted for by these variables is the excess return ε_t .

At the same return period t , the chapter models domestic daytime return on the JSE as:

$$JDR_t = \alpha_2 + \beta_3 JDR_{t-1} + \phi_i L^i \varepsilon_t + \beta_4 DH + \mu_t \quad (5.02)$$

Where L^i is the Lag Operator of ε_t , up to i lags.

In addition to the variables included in the formulation of the foreign Day return in equation (5.01), this domestic Day return equation incorporates ε_t , the excess return on the foreign bourse for period t , at i lag(s). The coefficient associated with ε_t is the relationship between foreign returns and JSE returns, up to i lags, one of the two associations investigated in this chapter.

The second association this chapter investigates is that of the volatility on the foreign bourse and volatility on the JSE. This is done using an EGARCH(1,1) specification, where the excess return ε_t is distributed with a mean of zero and a variance that follows the process:

$$\ln h_{L,t} = \varpi_1 + \beta_5 \ln h_{L,t-1} + \gamma_1 \frac{\varepsilon_{L,t-1}}{h_{L,t-1}} + \alpha_1 \frac{|\varepsilon_{L,t-1}|}{h_{L,t-1}} \quad (5.03)$$

Here, the natural log of conditional variance of period t for ε_t is a function of the time invariable mean reversion value, ω , the natural log of past conditional variance, h_{t-1} , and both the level and absolute value of the standardised residuals, $\varepsilon_{t-1}/h_{t-1}$ and $|\varepsilon_{t-1}|/h_{t-1}$, respectively.

This (1,1) lag specification of a single ARCH term and a single GARCH term for modeling the volatility in this section was chosen following the analysis presented in chapter 3, which showed that this parsimonious specification adequately accommodated the domestic volatility structure.

Chapter 3 above provided evidence that the domestic equity market variance reacts asymmetrically to positive and negative price movements. EGARCH processes will address this asymmetry by making the conditional variance a function not only of the magnitude of past disturbances, but also the direction of them. While chapter 3 showed that the accommodation of the leverage effect was not necessary to sufficiently address the ARCH effects, an asymmetric model was employed a priori to further isolate the international from the domestic information. As discussed in that chapter, the EGARCH model is preferred over the TARCH as it allows for finer modeling of the exact moment of asymmetry, contributing further to the isolation of the foreign effect.

For domestic variance, the ‘excess’ return on the JSE, μ_t , is modeled according to a Factor EGARCH conditional variance process:

$$\ln h_{j,t} = \varpi_2 + \beta_6 \ln h_{j,t-1} + \gamma_2 \frac{\varepsilon_{j,t-1}}{h_{j,t-1}} + \alpha_2 \frac{|\varepsilon_{j,t-1}|}{h_{j,t-1}} + \kappa_i L^i h_{L,t} \quad (5.04)$$

Where the subscripts j and l denote domestic (JSE) and foreign (LSE) measures, respectively.

As with the formulation of the domestic return in equation (5.02), this specification of the variance of the JSE includes a foreign measure, $h_{L,t}$, in addition to the variables included in

the specification of the variance of the foreign return in equation (5.03). This allows for the explicit testing of the association between local volatility and foreign volatility, up to i lags. The foreign conditional variance term in equation (5.04), $\kappa_i L^i h_{l,t}$, is the association between foreign volatility and domestic volatility.

The model as outlined above thus formally tests for the association of both returns and volatility on the JSE and the foreign equity market. Following Lin, Engle and Ito (1994) it was estimated using a two step process. In step one equations (5.01) and (5.03) were estimated, and the fitted values of ε_t and $h_{L,t}$ obtained. Equations (5.02) and (5.04) were then estimated using these fitted values, the results of which are presented in section 5.7 below. As the residuals ('excess returns') were suspected of being leptokurtic (see section 1.3.2), Bollerslev and Wooldridge (1992) quasi-maximum likelihood (QML) covariances and standard errors were (as always) computed.

5.6 Causation and Association

Before the results of the estimation are examined it needs to be made clear what the results actually indicate. The hypothesised link that is held by many market watchers is that the behavior on the international markets *cause* certain behavior on the domestic market. Higher returns on the LSE, under this view, *cause* higher returns on the JSE by *themselves*. However, as will be seen shortly, the dominant relationships between the domestic and foreign markets are concurrent, occurring during the same trading period. Movements on the LSE on a respective day are correlated with movements on the JSE predominately on that very same day. Given that the chapter uses daily data, it is impossible to infer direction, or specifically cause, from this methodology. Rather, the chapter's methodology tests for evidence of *association*, not *causation*. What is tested is whether domestic market returns and volatilities are associated with domestic market returns and volatilities, not whether they *cause* domestic market returns and volatilities.

Given the relative size difference, there is the obvious tendency to interpret the associations as the LSE's behavior (at least partially) driving the JSE's during a certain period. However, it may well be that any significant international concurrent relationships that are found represent not a causal transmission from the LSE to the JSE but reactions to some common globally relevant signal interpreted by both domestic and foreign market participants as independently influencing their respective indices. A change in the world gold price, for example, would affect gold producing companies in all countries directly. Even evidence of a significant relationship between the lagged behavior of foreign markets and current domestic markets cannot be interpreted as providing evidence of causality, even of the specific Granger type. Lags would be present regardless of the existence of directional causality if markets in both countries take longer than one trading period to correctly price in the new information provided by some global signal. Significant lagged effects would also be present if a certain market incorporated new globally relevant information faster than another market, but even under these conditions it cannot be said that the one market's behavior is *causing* the other market's behavior, it is simply leading it in time.

This problem of separating globally relevant market signals from the effects caused entirely by international market movements (pure contagion) is a classic signal extraction problem. Together, these two effects combine to form the global factor, with the result being that this chapter can only discuss domestic returns and volatilities as being *associated* with foreign returns and volatilities, not *caused* by them. However, while this chapter cannot state that domestic market movements are *caused* to a certain extent by international markets, it can estimate the degree that local markets are *affected* by the global factor, using the LSE returns and volatilities as a proxy for it. In other words, the chapter estimates the existence, magnitude and direction the global factor exerts on the JSE, where the global factor consists of both foreign bourse behavior and globally relevant market signals.

5.7 International Association Results

The results of the relationship tests are given in tables 10, 11 and 12 below. Table 10 shows the effects for each individual year of this study, from 1996 to 2004, for the broad indexes as a whole. For each year both the significant association periods and the magnitude of the global factor effects are estimated.

Addressing the problem of differing bourse compositions, Table 11 extends the same analysis to each of the nine sub-sectors of the JSE. Two things should be kept in mind when examining this table. Firstly, the estimated effects are for the period as a whole and, secondly, the relationships tested are those between a respective LSE sector and the same respective JSE sector. The results given for the Basic Industries index, for example, concerns the association between the returns and volatilities of the LSE's Basic Industries index and the returns and volatilities of the JSE's Basic Industries index.

In order to gain further insight, Table 12 concludes the analysis into the global factor by providing some insight into its magnitude and direction, through the main association period, on the JSE by providing the coefficient estimates of the main foreign variables for each sector. In addition Table 12 also provides evidence supporting the use of the EGARCH methodology to model the foreign effect.

Table 10: Returns and Volatility Association between the LSE and the JSE, by Year

	Returns Association			Volatility Association			Explanatory Power of International Equity Market [‡]
	Concurrent Association	Main Association Period*	Sig. Period(s) [†]	Concurrent Association	Main Association Period*	Sig. Period(s) [†]	
1996	Yes	Concurrent, t	t	No	-	-	10,3%
1997	Yes	Concurrent, t	t	Yes	Concurrent, t	t	10,5%
1998	Yes	Concurrent, t	t	Yes	Concurrent, t	t	36,6%
1999	Yes	Concurrent, t	t	No	-	-	20,9%
2000	Yes	Concurrent, t	t, t-1	Yes	Concurrent, t	t, t-1	16,1%
2001	Yes	Concurrent, t	t, t-1	Yes	Concurrent, t	t	20,5%
2002	Yes	Concurrent, t	t, t-1	No	-	-	20,7%
2003	Yes	Concurrent, t	t, t-1	No	-	-	22,0%
2004	Yes	Concurrent, t	t, t-1	Yes	Concurrent, t	t, t-1	14,9%
Full Sample	Yes	Concurrent, t	t, t-1	Yes	Concurrent, t	t, t-1	21,0%

Notes:

Daily data, sample period 01/01/1996 to 31/12/2004, for a total of 2 351 observations.

* Defined as the most significant period.

A dash (-) indicates that the respective series contained no significant associations.

[†] Significant at the 5% level.

[‡] Defined as the change in the Adjusted R² of the estimation of the relevant equation with and without the significant international variables.

The results provided in Table 10 (above) provide strong evidence to suggest that the returns on the JSE are most associated with international returns during the very same trading period for every year of the study. During the latter half of the period, from 2000 to 2004, there is

also evidence of a one period lag effect of international returns on local returns. The relationship between domestic and foreign volatility, in contrast, is more mixed. For four of the nine years there is no evidence of any significant relationship, concurrent or lagged, between domestic volatility and foreign volatility, while for other three years there is only evidence of a concurrent relationship. In the years 2000 and 2004, in contrast there is evidence of a lag effect in addition to a dominant concurrent effect.

The average explanatory power of the foreign effects is 19,1%, although it differs greatly between the years. The global factor is most important in 1998 (36,6%) and the least important in 1996 (10,3%). For the full period as a whole, from the 1st of January 1996 until the 31st of December 2004, 21,0% of the movement of the ALSI40 was associated with the movements on the FTSE100, implying that in general around one fifth of the local equity market's daily behavior is determined outside of South Africa.

Table 11: Returns and Volatility Association between the LSE and the JSE, by Sector

	Returns Association			Volatility Association			
	Concurrent Association	Main Association Period*	Sig. Period(s) [†]	Concurrent Association	Main Association Period*	Sig. Period(s) [†]	Explanatory Power of International Equity Market [‡]
Basic Indus.	Yes	Concurrent	t, t-2	No	Lag, t-1	t-1/2	10,1%
Cyc. Cns. Gds	Yes	Concurrent,	t, t-1/3/4	No	None	None	3,9%
Cyc. Services	Yes	Concurrent,	t, t-1	Yes	Concurrent,	t, t-1	16,3%
Financials	Yes	Concurrent,	t, t-1	Yes	Concurrent,	t, t-1	18,4%
Gen. Ind.	Yes	Concurrent,	t, t-1/2	No	None	None	8,3%
Inform. Tech.	Yes	Concurrent,	t, t-1/2/3/4/5/6	Yes	Concurrent,	t, t-1/2/3	14,2%
NC Cons. Gds	Yes	Concurrent,	t, t-1	Yes	Concurrent,	t, t-1/2	5,4%
NC Services	Yes	Concurrent,	t, t-1	Yes	Concurrent,	t, t-1	7,2%
Resources	Yes	Concurrent,	t, t-1	Yes	Concurrent,	t, t-1/2/3	9,1%

Notes:

Daily data, sample period 01/01/1996 to 31/12/2004, for a total of 2 351 observations.

* Defined as the most significant period.

A dash (-) indicates that the respective series contained no significant associations.

[†] Significant at the 5% level.

[‡] Defined as the change in the Adjusted R² of the estimation of the relevant equation with and without the significant international variables.

Table 11 (above) extends the analysis by estimating the main association periods for both returns and volatilities. As can be seen, in every sector the dominant return period is during the same concurrent trading period, although there is also strong evidence of additional lagged

associations being present as well. The Information Technology sector, for example, experiences the effects of return movements on the LSE up to six periods later, and Cyclical Consumer Goods up to four periods later.

As was found with the yearly analysis, the association of international volatility is again markedly different from the association of returns. In some sectors, namely the Cyclical Consumer Goods and General Industries, there are no significant effects of international volatility at all. In contrast, global volatility affects local volatility on the Basic Industries sector not concurrently but at lags of one and two periods later. In the other six sectors though international volatility was found to significantly affect domestic volatility during the same concurrent trading period; and with most of those sectors having additional lagged relationships.

As also shown in Table 11, the sectors differ not only in respect to when the global factors affect them but also to the degree that they are affected. The most globally affected sectors on the JSE are the Financial, Cyclical Services and Information Technology sectors, with foreign factors explaining 18,4%, 16,3% and 14,2% of the movement in their returns, respectively. The sectors found to be least globally affected using this methodology were the Cyclical Consumer Goods sector (3,9%) and the non-Cyclical Consumer Goods sector (5,4%). A possible explanation for this low is that these consumer based sectors are determined more by local conditions than by global factors.

Table 12: Effects of Main Returns and Volatility Association between the LSE and the JSE

Main Variable of Returns [*]				Main Variable of Volatility [*]				
	Period	Coefficient	P-Value	Period	Coefficient	P-Value	γ	$\gamma=0^{\dagger}$
Basic Industries	t	0,464	0,000	t-1	0,596	0,000	-0,003	0,659
Cyc. Cons. Gds	t	0,210	0,000	-	-	-	-0,072	0,000
Cyc. Services	t	0,336	0,000	t	0,450	0,000	-0,023	0,000
Financials	t	0,334	0,000	t	0,376	0,000	-0,044	0,000
Gen. Industries	t	0,254	0,000	-	-	-	-0,061	0,000
Inform. Tech.	t	0,492	0,000	t	0,160	0,000	-0,128	0,000
NC. Cons. Gds	t	0,232	0,000	t	0,941	0,000	-0,012	0,073
NC. Services	t	0,254	0,000	t	0,250	0,000	-0,026	0,002
Resources	t	0,277	0,000	t	0,601	0,000	-0,014	0,031
Full Index	t	0,425	0,000	t	0,560	0,000	-0,036	0,000

Notes:

^{*} Defined as the most significant period.[†] Wald Test F-Stats' P-Value: Null: $\gamma=0$.

A dash (-) indicates that the respective series contained no significant associations.

The last two columns of Table 12 above, provide estimates of the coefficient of γ , the EGARCH term. As can be seen, with the exception of the Basic Industries sub-indices the null hypotheses of symmetry ($\gamma=0$) can be rejected for all sub-indices and for the index as a whole, validating the use of EGARCH modeling. For eight of the nine sectors, and for the broad index as a whole, the null hypothesis of symmetric responses to both goods news and bad news can be rejected at the 5% level, with the additional ninth sector, Non Cyclical Consumer Goods, being rejected at the 10% level. Basic Industries appears to be the only sub-index where symmetric responses to past returns cannot be rejected. In general though, the estimated coefficients suggest that the volatility on the markets reacts far more to negative returns (bad news) than to positive returns (good news); negative market returns appear to have a far greater effect on the magnitude of current volatility than do positive past errors. This concurs with the evidence of a significant leverage effect in the broad domestic index found in chapter 3.

As can also be seen in table 12 the effect of both international returns and volatility on the JSE is positive for all nine sub-indices and for the ALSI40 as a whole. Positive returns on the LSE are associated with positive returns on the JSE, and negative LSE returns with negative returns on the JSE. For the Basic Industries sub-indices for example, an increase in the sub-index on the LSE by 1 percent is associated with a 0,464 percent increase in respective index on the JSE. For the Financial sub-index, the respective relationship is a 0,334 percent increase in the JSE sub-index for a one percent return on the LSE Financial sub-index. For the JSE

ALSI40 index as a whole over the full period, a one percent increase in the LSE FTSE 100 index is associated with a 0,425 percent increase in the ALSI40 index.

The estimated relationships between foreign and domestic volatility during the same trading day are also found to be positive. Higher volatility on the LSE is associated with higher volatility on the JSE, and lower LSE volatility with lower JSE volatility. This is true for the ALSI40 index as a whole and for all sub-indices except for the General Industries sector, where no significant international association was found. However, while the relationships were all found to be positive, there was a large difference in the magnitude of the effects. The volatility of the Non Cyclical Consumer Goods sector, for example, increases by 0,941 units for every one unit increase in the volatility on the same sector on the LSE, an almost unitary relationship. In contrast, the relevant figures for the Information Technology is only a 0,160 unit increase for every unit increase in volatility on that respective sector on the LSE. For the JSE as a whole, this chapter found that a one unit increase in volatility on the FTSE100 is associated with a 0,560 unit increase in volatility on the ALSI40 during the same trading day.

5.8 International Conclusions

This chapter tested empirically the widely held view that the JSE's behavior is associated with international market behavior. Using the LSE as a proxy for the international market, this chapter found five significant results regarding this international/local relationship.

The first is that there exists a positive relationship between domestic market returns and international market returns. Bullish (bearish) international returns were found to be associated with bullish (bearish) domestic returns.

The second result is that there also exists a positive relationship between domestic and international volatility. Periods of higher (lower) international volatility were found to be, on the whole, associated with periods of higher (lower) domestic volatility.

Another important outcome of this study was that these two positive associations were found to exist principally during the same concurrent trading period. The behavior of the JSE on a certain day was found to be primarily associated with international market behavior during that concurrent trading period, implying that foreign markets cannot be used as a signal of future JSE behavior. However, this result needs to be qualified in noting that this study used daily return periods to investigate the relationship, whereas equity price changes happen at far smaller intervals. Using finer grained data it could well be established that international market movements anticipate local market movements, though it is questionable how stable this relationship would be.

The fourth result generated using this analysis is that the global relationships that were found were far from universal. A large degree of heterogeneity was found to exist across different years and different sectors with respect to the existence, magnitude and importance of global factors.

The fifth and final insight concerns the relative importance of domestic and foreign information. It is clear that international information plays a secondary role to domestic information in price determination on the JSE. For the period under a review, only a fifth of the movement on the JSE can be explained by foreign equity market behavior. This is highest during 1998, where roughly a third of domestic price movement is explained by the global market, and is lowest in 1996, with only a tenth. Domestic market information is therefore far more important to the domestic equity market, and by quite a large degree. This is true also for the individual sectors, where the sector where foreign information plays the largest role (Financials) still has four-fifths of its movement explained by local information.

In conclusion then, while caution must be exercised in inferring causation, this chapter found that the widely held view that domestic market behavior is associated with international market behavior has some empirical legitimacy. With this understanding, the following chapter attempts to estimate the impact this association has on the domestic risk-return relationship.

CHAPTER 6

THE GLOBALISED SA RISK-RETURN RELATIONSHIP³⁰

6.1 Introduction

At the heart of the study and practice of financial economics is the fundamental relationship between risk and return; being risk-averse, investors require higher returns to compensate them for accepting higher risk. This is the reason why junk bonds, for example, pay higher rates of return than government bonds, and why start-up firms raise capital at much higher interest rates than blue chip firms do. It is also the reason why equities provide greater returns than other, less risky investment classes, such as cash or bonds over a medium to long-term horizon. In an efficient market accepting risk is rewarded; however, and this is basis for financial research, not all risks are equally rewarded. “Optimal investment behavior”, as Engle (2004) states in his Nobel lecture, “takes risks that are worthwhile”, seeking out strategies that maximise expected returns and minimise expected risks.

Within the equity market this avoidance of risk leads naturally to a policy of portfolio diversification. As it is unlikely that any two given equities are perfectly correlated with each other, holding more than one equity asset leads to a reduction in risk as the various movements of the assets’ partially offset each other. Taking this strategy to its fullest extent possible, the most diversified exclusively equity portfolio an investor can hold consists of all of the assets held in proportion to their market capitalisation, a portfolio known as the market portfolio. The fully diversified property of the market portfolio ensures that its variance, or risk, plays an important role in defining the ‘base’ level of risk in an equity market. For example, in the well-known Capital Asset Pricing Model (CAPM) of Sharpe (1964) and

³⁰ A version of this chapter was published as a journal article in the South African Journal of Economics, September 2007, entitled “The Price of Risk on the JSE”. It also appeared as an Economic Research South Africa (ERSA) working paper (WP#49) under the same name. Those papers, and thus indirectly this chapter, benefited greatly from comments and insights made by Corné van Walbeek, Grant Shannon and anonymous referees from both ERSA and the SAJE. Funding from ERSA for this chapter and subsequent article is gratefully acknowledged.

Litner (1965) the risk premium of the equity market is determined by the market price of risk (related to the risk averseness of the investors) multiplied by the variance of the market portfolio.

However, in South Africa's globally open equity market it is possible to diversify further than the market portfolio by investing in the international equity market. This investment behavior allows for further risk reduction, as the international equity market and the JSE, while tending to move together in general, are imperfectly correlated given their respective local market conditions and differing bourse compositions. This imperfect yet significant relationship was investigated in the previous chapter.

The diversification aspect of an international portfolio obviously depends on the degree to which the returns on the respective international bourses move together. From this risk-reducing portfolio perspective, investors seek decreased correlations between the equities markets and avoid increased correlations. From a risk-averse international equity portfolio's perspective, increased correlations are a risk that should be rewarded in an equity market such as South Africa's, in addition to the 'base' risk of the market portfolio.

As the capstone of this study into the risks and returns on the globalised South African equity market, this final chapter will investigate empirically the risk-return relationship on the internationally open Johannesburg Securities Exchange (JSE) by focusing on the returns to these two risks. Accounting for the forward looking nature of equity investing, it will do so by focusing on the relationship between the expected return on the market portfolio, its' expected variance (domestic risk) and its expected covariance (international diversification risk) with the international equity market. As always, the chapter will use the London Stock Exchange (LSE) as the global market proxy. Furthermore, the chapter will investigate these domestic and international risk prices within a framework that accommodates the three important and salient properties of the JSE found in this study so far.

Firstly, the framework allows for international spillover effects between the international equity market and the domestic market found in the previous chapter. To recall, that chapter found a significant relationship between the JSE and the LSE returns and volatilities, chiefly through the same concurrent trading day. To accommodate this important source of information regarding domestic equity movements this risk-return study will follow the same methodology of Lin, Engle and Ito (1994) used in the preceding chapter. A Factor ARCH volatility specification will be employed that accommodates the spillover relationship between foreign and domestic volatilities. This explicit inclusion will allow for the better modeling of the domestic volatility process. Note that, to avoid obscuring the risk return relationship (the main focus of this chapter), the spill over process for mean returns was not accommodated directly using the same process. Rather, it is accommodated indirectly by looking at the return to the covariance between domestic and international returns. This is discussed in much greater detail below.

Secondly, the model accommodates the well-documented time-variation in both the variances and covariances of the equity returns. Volatility clustering, where volatile periods follow similar volatile periods, and calm periods follow equally calm periods, is an innate property of financial time series. This is because a large return in a certain direction is often followed by another large return of a similar magnitude, either in the same direction (herding behavior) or in the opposite direction (mean reversion behavior or correction) as market participants endeavour to correctly price in the new information. Likewise, small returns in a certain direction tend to follow small returns of a similar magnitude, again in either direction. As international equity markets tend to move together this clustering property is also apparent in the covariance between two or more equity markets. This investigation was the focus of chapter 3. Following that chapters results, this chapter will employ ARCH processes to model the variances and covariances of the two markets under review.

Lastly, to properly investigate the returns to risk on the JSE, both returns and risks must be adequately modeled. In this light, returns will be modeled according to the weak form efficient specification justified in chapter 2, while risks will be modeled according to the GARCH(1,1) specification, which chapter 3 found was able to sufficiently model SA equity volatility.

The structure of this chapter is as follows. The next section discusses the price of risk and the Intertemporal Capital Asset Pricing Model used in this chapter, while section 6.3 presents the literature review. Section 6.4 provides the econometric specification of such an ICAPM model, while Section 6.5 provides the results and analysis. Section 6.6 concludes.

6.2 The Intertemporal CAPM and the Price of Risk

The basis for this domestic risk-return chapter is the Intertemporal Capital Asset Pricing Model (ICAPM) of Merton (1973). This is the multi-period extension of the static CAPM, and holds that investors attempt to maximise utility over the total investment horizon. Whereas the CAPM implies a simple relationship between the market risk premium and the conditional risk premium, the ICAPM is a multifactor asset-pricing model where the risk premium on an equity market is a function of whatever risk source(s) the representative investor decides to price, or impound, into the asset price. Given the characteristics of equity returns, the conditional market variance is usually one of the risk factors. Given the open nature of the JSE, this study investigates the hypothesis that the representative investor on the JSE, in addition to pricing in market variance risk, prices in the risk surrounding the loss of diversification benefits.

6.2.1 Variance and Covariance Risk

As argued in chapter 3, that the expected variance of returns is a major, if not *the* major, source of risk amongst equities has a long history in financial economics. It is by far the standard risk measure in the equity risk-return literature. As the definition of an equity return is the movement of its market price, the expected variance associated with this expected return is a direct measure of future uncertainty (or risk) surrounding such an investment. In the literature, the expected return per unit of the expected variance of returns is often termed Lambda (λ), a convention this chapter will follow in describing the risk price. Given the risk-averseness of the representative investor, it is expected a priori that Lambda will be both

significant and positive in the South African equity market. This is because the risk-return relationship states that in an efficient market the expected return should be higher if the expected uncertainty of that return is higher, provided the market prices in this domestic variance risk.

The second risk factor explored in this chapter concerns the uncertainty around international diversification. In the relatively open South African equity market, international investors are able to invest in domestic assets and, conversely, domestic investors are able (to a large degree) to invest in international assets³¹. While obviously seeking higher risk adjusted returns, a significant attraction of this cross border investing must be due to the increase in diversification generated from such cross border portfolios. Given the imperfect correlations amongst international equity markets seen in chapter 5, investing in offshore equities should reduce some of the risk of investing in domestic equities. From such an international portfolio investor's perspective the less correlated the domestic market is with the international market the better this diversification property of the JSE, and vice versa. Assuming that risk-averse investors desire this diversification property, the domestic market will price this increased covariance between the domestic and international market into the domestic market as a risk. In an efficient market, therefore, investors valuing international diversification should receive a higher expected return in compensation for the higher expected covariance. A-priori, the expected price of this covariance risk should be positive. As there appears to be no universal name for such risk in the literature, this chapter will refer to this covariance risk as Kappa (κ).

It is important to note that this international risk discussed here and investigated in this chapter is covariance risk, and not contagion or transmission risk. While clearly related, these two risks have very different effects on the risk-return relationship. Covariance risk is due to the decrease in the diversification benefit as domestic and international returns move more closely together. Contagion or transmission risk, on the other hand, is the risk that international equity price movements will affect domestic price movements, and was the

³¹ Restrictions on foreigners were almost non-existent by the start of the period under review. Specifically, both the need to use the Financial Rand for foreign capital inflows and the SA citizenship requirement for stock broking were abolished in March and November of 1995, respectively. Domestic investors remain restricted in the amount of capital they can invest in foreign markets, though this restriction is gradually being reduced over time.

focus of chapter 5. This is due to the tendency of investors to price in information from outside the borders of their respective country into their own equity market, leading to price movements internationally ‘spilling over’ into the domestic equity market. While clearly a risk, this relationship is priced in indirectly in this chapter through its affect of the domestic volatility level. As such, there is no ‘contagion price’ or ‘transmission price’ estimated in this chapter. The price of covariance risk in contrast *is* investigated in this chapter; being captured in the conditional covariance term in the conditional first moment specifications of the respective returns. (See below for the exact specification of these effects and further discussion.)

There are thus two distinct though related international effects investigated and accommodated in this study. The chapter accommodates the spillover effect of the previous chapter, whereby increased volatility on the international market is associated with increased volatility on the domestic market, through the inclusion of the foreign volatility in the specification of the domestic volatility. Covariance risk, where the international and domestic market move more closely with each other and therefore lessen the diversification effect, is accommodated though the inclusion of the estimated conditional covariance in the specification of the domestic return. This modeling of two distinct effects from the same source, with one effect priced in by the market as a risk and the other a contributing factor affecting the volatility, follows the exact procedure used by Dean and Faff (2001) to incorporate bond market risk into their ICAPM model of Australian equity returns.

6.2.2 The Intertemporal Capital Asset Pricing Model

With this understanding, as a starting point for the specification used in this chapter to price the two risks, define the return premium for asset (i), ($r_{i,t}$), as the nominal return ($R_{i,t}$) less the risk free rate return ($R_{iF,t}$) for time period t as:

$$r_{i,t} = R_{i,t} - R_{iF,t} \quad (6.01)$$

In the standard CAPM model there is a simple proportional relationship between the market risk premium $r_{i,t}$ and one risk factor, the conditional risk premium:

$$E[r_{i,t} | \Omega_{t-1}] = \beta_A E[\text{var}(r_{i,t} | \Omega_{t-1})] \quad (6.02)$$

Where $E[\cdot | \Omega_{t-1}]$ is the expectational operator conditional on information known in the immediately preceding period (Ω_{t-1}).

Then, the two-factor ICAPM extension of the CAPM model has the market risk premium of portfolio (i) being proportional to the covariance of the returns with the returns of two risk factors, A and B:

$$E[r_{i,t} | \Omega_{t-1}] = \beta_A E[\text{cov}(r_{i,t}, r_{A,t} | \Omega_{t-1})] + \beta_B E[\text{cov}(r_{i,t}, r_{B,t} | \Omega_{t-1})] \quad (6.03)$$

The ICAPM specification of the market portfolio used in this paper has the international market being one factor and the domestic market portfolio being the other. Noting that the covariance of the market portfolio with itself is by definition the variance of the market portfolio, the ICAPM specification for an international market portfolio J is specified as:

$$E[r_{J,t} | \Omega_{t-1}] = \lambda_{\text{var}} E[\text{var}(r_{J,t} | \Omega_{t-1})] + \kappa_{\text{cov}} E[\text{cov}(r_{J,t}, r_{L,t} | \Omega_{t-1})] \quad (6.04)$$

where the expected return premium on the international equity portfolio is proportional to the expected variance risk of that portfolio and proportional to the expected covariance risk of the portfolio with the international equity market. $r_{J,t}$ and $r_{L,t}$ are the excess returns on the JSE and the foreign market (LSE) for time period t, λ_{var} is the price of domestic risk Lambda and κ_{cov} is the price of covariance risk Kappa. Equation (6.04) thus gives the relationship at time (t) between the expected market return premium, the expected domestic market risk and the expected international market risk, all conditional on the information known at period (t-1).

6.2.3 A Unit of Risk

Given the construction of variance measure casual interpretation of the return per unit of risk is conceptually untidy as the power transformation of the variance specification renders easy interpretation and application of the variance units messy. The simplest case is the

interpretation of one unit of risk, which, assuming a symmetrical distribution, can be seen as a level of uncertainty corresponding to a full 1,00% return above or below the expected return. Interpretations of higher variance amounts quickly lose their practical traction. Two units of risk, for example, correspond to a level of return uncertainty of approximately 1,41% ($\sqrt{2}$) above or below the expected return; three units correspond to 1,73% ($\sqrt{3}$) above or below. For ease of interpretation, this chapter will frame all discussion of the returns to risk in terms of returns per single unit of risk, equivalent to a level of uncertainty of a full 1-percentage return around the expected return.

6.2.4 Market Segmentation and Benefits from International Diversification

An interesting aspect to this dual study of domestic and international risk, as outlined by De Santis and Gerard (1997), is that it is possible to infer some information about the integration of the domestic market with the international market, at least in an absolute manner of integration, from the relative returns to these two risks. This outcome would be complementary to the insight from the previous chapter, where international factors played a minor role in domestic price determination compared to domestic factors.

Following the methodology of this chapter, a market perfectly integrated with the international equity market (in the extreme sense of word), would have all of the significant information regarding the risk return relationship contained in the international market risk term, and the information regarding domestic risk would not matter. Evidence then of a significant country specific risk in the estimation of the equity returns which also contains the international risk information could be seen as suggesting that the local market is not perfectly integrated with the world equity market. There would be at least some market segmentation on the national level as domestic risk information is still significant in explaining the equity returns. While not a principle focus of this study, the econometric framework employed will allow this segmentation hypothesis to be tested: if the domestic market was perfectly integrated internationally only international information would matter, making Lambda in equation (6.04) insignificant. As such, following De Santis and Gerard (1997), equation (6.04) is also a test of market integration, if only at a very broad level.

De Santis and Gerard (1997) also show that the estimation of the returns to such an international portfolio can be used to gauge the gains from international diversification. Consider a domestic equity investor with no international investments, i.e. a portfolio composed entirely of domestic assets. According to equation (6.04), including foreign equities in this portfolio will expose the representative investor to diversification risk, which will provide an expected payoff of $(\kappa_{\text{cov}} E[\text{cov}(r_{j,t}, r_{L,t} | \Omega_{t-1})])$. It is clear that, by definition, the domestic portfolio has a volatility level of the domestic market portfolio, $(E[\text{var}(r_{j,t} | \Omega_{t-1})])$. It should also be clear that, for the same level of volatility, an internationally diversified portfolio has an increase in returns equal to $(\kappa_{\text{cov}} E[\text{var}(r_{j,t} | \Omega_{t-1})])$. Therefore, following De Santis and Gerard for a level of risk equal to the domestic level the expected gain to a portfolio with international diversification over a portfolio with zero international diversification portfolio is given by:

$$E[r_{\text{diversified},t} - r_{\text{closed},t} | \Omega_{t-1}] = \kappa_{\text{cov}} E[\text{var}(r_{J,t} | \Omega_{t-1}) - \text{cov}(r_{J,t}, r_{L,t} | \Omega_{t-1})] \quad (6.05)$$

The estimation of equation (6.05) will therefore also allow for the indirect investigation of the possible gains to local investors having for an internationally diversified portfolio. Given the imperfectly correlation of international equity market movements, the international diversification property should lead to benefits for domestic investors. As such, it is expected a priori that the relationship outlined in equation (6.05) above will be positive, and domestic investors rewarded by the openness of the JSE.

6.3 Risk-Return Literature Review

Given the importance of estimating the compensation for risk, it is not surprising that this has been a very productive research field. However, it is worrying that despite there being a strong theoretical reason for the existence of a positive return to these risks, there is no consensus in the literature regarding the size, significance or even the sign of such a risk price coefficients.

For example, looking at the major world equity markets first, French, Schwert and Stambaugh (1987), using daily returns on the S&P index, find a positive though insignificant price estimate of domestic risk of 0,023% using a GARCH-M model. Chou, Engle and Kane (1992) use a Kalman filter and a time varying ARCH-M model on weekly S&P composite index returns and find that the price of domestic risk is both significant and positive, though highly time-varying. Using a methodology similar to this chapter, De Santis and Gerard (1997) find that the US market prices in both variance and covariance risk. In complete contrast, Glosten, Jagannathan and Runkle (1993) find a significant negative relationship between domestic variance and returns on the US equity market, a finding that is difficult to reconcile with the other empirical studies and conventional asset valuation theory³². This negative result is also found by Campbell (1987) and Pagan and Hong (1991). Chan, Karolyi and Stulz (1992), meanwhile, employing a bivariate GARCH-in-Mean specification on daily S&P 500 data, find that the US market impounds in the covariance risk with of the world equity market but does not impound domestic variance³³ information.

In terms of smaller equity markets, Hansson and Hördahl (1997) apply various ARCH processes specifications to modeling the price of risk on the Swedish equity market, which, in being both small, liquid and relatively open, is similar in many ways to the JSE. Using a standard one factor CAPM their paper generates estimates of Lambda for daily equity index returns ranging from 0,050% to 0,075%. Dean and Faff (2001), in a very similar methodology to this chapter, investigate the return to risk on weekly Australian equity returns according to a two factor ICAPM mode estimated using an EGARCH(1,1)-in-mean model (which allowed for asymmetric variance dynamics) and a dynamic conditional correlation for cross over effects. Focusing on the return to domestic variance risk and covariance risk with regards to the bond market, they find returns to the risks of 0,0876% to 0,0993% and -1,273% to -1,786%, respectively. Jochum (1999), using a bivariate GARCH(1,1)-in-Mean methodology, estimates the price of variance and covariance risk of the Swiss Market Index (SMI) daily

³² There are two possible theoretical reasons whereby such a negative relationship might exist (Glosten, Jagannathan and Runke, 1993). Firstly, it may be, by coincidence, that investors are able to bear higher levels of risk during the risky periods. Secondly, if there is no/limited risk free asset(s) and investors wish to save more during a risky period then they will bid up the price of the risky assets (equities) and hence reduce the risk premium and cause a negative relationship to exist. See, amongst others, Abel (1988) and Glosten and Jagannathan (1987) regarding such theoretical models.

³³ However, they point out that this is probably due to a large degree of multicollinearity between the two risks in their sample, given the dominant contribution, and hence closer relation, of the US equity market to the world equity market. This is unlikely to be a concern of the JSE, given its far smaller size.

returns with regards to the major equity markets of Tokyo, Frankfurt, London and New York. It is not clear how the paper addresses the problem of non-concurrent trading hours. Using a peculiar weighting procedure, whereby the two risks are weighted in proportion to their respective market capitalisation, the paper finds significant evidence that the covariance risk is significant and positive for all the markets except Frankfurt. This daily covariance risk price ranges from 0,089% for Zurich-Tokyo to 0,396% for Zurich-London. Surprisingly, though in line with Chan, Karolyi and Stulz (1992), Jochum finds no significant price for domestic risk, though this may be due to the very small importance attached to domestic information given the weighting procedure used in the study.

In South Africa, the risk-return relationship has attracted considerable interest, though these largely focus on the ex-post relationships and/or use incomparable non-econometric techniques such as the well-known Sharpe Ratio. To the authors' knowledge, this is the first econometric study of the conditional returns to conditional risks amongst domestic equities using a GARCH-M methodology comparable to the studies reviewed above.

Scruggs (1998) provides a plausible explanation for such widely disparate empirical results in the literature, despite the strong theoretical basis. Investors' price assets according to many different risk factors, and as such the risk return relationship is complex and multifaceted. By using the simple one factor CAPM model, Scruggs argues, many of the studies outlined above ignore important information about the risk structure, to the degree that the bias caused by the omitted variable could significantly distort the results.

Through positing that some significant information that investors price into the market in an open, small equity market such as South Africa's is partly domestic risk and partly international diversification risk, this chapter attempts to add to the risk pricing literature as well as counter the problem of insufficient risk specification mentioned by Scruggs (1998). Indeed, this positing of the international diversification effect as another risk factor of key importance to an open equity market such as South Africa's is a key innovation in this paper. In this light, to test Scruggs's argument that the simple CAPM will provide distorted values of

Lambda, this chapter will also test the standard CAPM as an additional risk return model for comparison sake.

6.4 Methodology

6.4.1 ICAPM Econometric Specification

For this empirical study equation (6.04) outlined in section 6.2 is investigated using a parsimonious bivariate GARCH(1,1)-in-Mean specification. Following the ICAPM model the returns on the JSE are modeled as being a function of their own variance and its covariance with the LSE returns. The LSE returns are in turn modeled following a CAPM model, being a function of their own variance only. For both of these the conditional means are regressed upon the conditional variance (and covariances) of the indexes following the ARCH-in-Mean methodology of Engle, Lillian and Robbins (1987). The variances of both the LSE and JSE returns are specified according to a GARCH(1,1) specification. The covariance is modeled according to a GARCH(1,1) type specification, including an explicit international spillover term.

Specifically, the econometric formulation of equation (6.04) above is given by:

First Moments:

$$r_{J,t} = \lambda_J h_{J,t} + \kappa_j \text{cov}_{JL,t} + \tau_J \text{out} + \varepsilon_{J,t} \quad (6.06)$$

$$r_{L,t} = \lambda_L h_{L,t} + \varepsilon_{L,t} \quad (6.07)$$

With

$$\varepsilon_{J,t} \sim (0, h_{J,t}) \quad (6.06')$$

$$\varepsilon_{L,t} \sim (0, h_{L,t}) \quad (6.07')$$

Second Moments:

$$h_{J,t} = \omega_1 + \beta_1 h_{J,t-1} + \rho_1 h_{L,t} + \alpha_1 \varepsilon_{J,t-1}^2 \quad (6.08)$$

$$h_{L,t} = \omega_2 + \beta_2 h_{L,t-1} + \alpha_2 \varepsilon_{L,t-1}^2 \quad (6.09)$$

$$\text{cov}_{JL,t} = \omega_3 + \beta_3 \text{cov}_{JL,t-1} + \alpha_3 \varepsilon_{J,t-1} \varepsilon_{L,t-1} \quad (6.10)$$

The equations for the first moments (equations (6.06) and (6.07)) follow directly from the ICAPM model outlined in section 6.2.2 above. The excess return is proportional to the domestic variance risk and proportional to the international covariance risk. Under the assumption of weak market efficiency argued in chapter 2, the realised return at period t is assumed to be an unbiased estimate of the conditional excess return expected at time $t-1$. The terms $h_{J,t}$, $h_{L,t}$ denote the estimated conditional variances of the JSE and LSE equities, respectively, for time period t estimated according to equations (6.08) and (6.09). The parameter $cov_{JL,t}$ is the conditional covariance between the equity returns on the JSE and LSE expected for time period t , estimated according to equation (6.10). The coefficients λ_J , λ_L and κ_J , κ_L give the returns to domestic variance and covariance risk on the JSE and LSE, respectively. These are the measures of variance and covariance price central to this study. As is standard in the literature these risk returns are assumed constant over the estimation horizon for reasons of tractability, implying that the slope of the Capital Market Line (CML) is constant. The τ_{out} term accommodates the outliers (see below) in the domestic equity returns. Finally, the residuals to these mean specifications are assumed to have a mean of zero and a variance of h_{it} .

The variance equations (6.08) and (6.09) are standard GARCH(1,1) specifications of the volatility structure. Amongst many others, Bollerslev, Chou and Kroner (1992) find that ARCH effects are highly significant in equity markets, and that the GARCH(1,1) framework provides a reasonably good and yet parsimonious specification of such time-variation. This was borne out in this study, where initial exploratory modeling in chapter 3 showed that the (1,1) structure adequately accommodated the ARCH effects in the returns according to the ARCH LM test. The variance equations consist of a mean reversion level of volatility ω_i , the β_i weighted one period lagged conditional variance and the α_i weighted squared residual return from the mean equation.

The domestic variance equation was adjusted in a Factor ARCH manner to accommodate the international spillover effects found in the previous chapter. This was done by including the conditional variance of the LSE for the same time period t in the conditional variance

equation for the JSE at time t . Following convention, this is called here, as it was in the previous chapter, the spillover term. With this modification, the effect of foreign information on the domestic market can be accommodated. This spillover modification was not repeated for the variance equation of the LSE for three reasons. Firstly, this study is primarily focused on the JSE and not the LSE, so the quantification of this effect is of no real interest here. Secondly, the initial OLS estimations show that the domestic conditional variance term is insignificant in explaining the conditional variance on the LSE, in contrast to the highly significant effect the conditional LSE variance has on the JSE variance. It appears that there is a LSE on the JSE effect but no JSE on the LSE affect. This is probably due to the large difference in relative market capitalisation between the two markets. Lastly, the inclusion of such a term adds unduly to the difficulty in finding convergence in such an already complex model.

It should be pointed out that an asymmetric version of the two conditional volatilities, for example EGARCH(1,1) or TARCH(1,1) models outlined above, were not used purely for computational constraints. While chapter 3 showed that the leverage effect, whereby negative returns are followed by increased volatility when compared to a positive return of the same magnitude, exists amongst domestic equities, the chapter argued that accommodating this feature was not required to sufficiently address the ARCH effects. This is advantageous, as attempts to find convergence in such an asymmetric specification for this chapter were not successful. Indeed, given the increased complexity of such a model this is not a unique finding, see Dean and Faff (2001).

The conditional covariance (equation (6.10)) has a similar time-varying structure to that of the conditional variances. It consists of a mean covariance level ω_3 and a one period lagged covariance weighted by β_3 . The α_3 weighted term consists of the interaction between the previous periods' residual returns, in this way it contributes to the covariance equation in the same way that the ARCH term's do in the variance equations. This term allows for the return innovations in the two respective markets to affect the conditional variance between them through both with their size and direction. The α_3 term should be positive as contemporaneous negative (or positive) returns on both indices imply an increase in covariance between both markets. In the same way, price movements in opposite directions imply less covariance

between the markets. In addition, the lagged covariance term accommodates the potential clustering of the covariance between the two markets. It is conceivable that, like the variances, periods of high levels of covariance are likely to follow periods of similar high covariance, and periods of low covariance followed by similar low covariance.

The model outlined above is thus an econometric specification of the domestic returns with domestic variance risk and covariance risk as the two sources of risk the typical investor is hypothesized to price in. Dealing with salient features of the domestic market it is modeled within a framework that accounts for both international spillover effects and time variance in the individual variances and overall covariance.

A final point is that this paper is concerned with the risk-return behavior over the entire sample, and the results should be read as such. Given the irregular nature of financial risks and returns, the relationships estimated are likely to display a large degree of time variation over the sample. The investigation of this time conditional aspect of risks and returns, as done by Chou, Engle and Kane (1992), was not undertaken in this paper for two reasons. Firstly, the use of the reduced sample periods needed for rolling regressions or sub-sample window estimations greatly reduces the likelihood of convergence. Indeed, finding sample periods sufficiently long to allow convergence yet short enough to provide meaningful insight into the time variation proved elusive. Separate estimations based on the annual sub-periods also proved fruitless as the heuristic failed to find a solution for many of the years. Secondly, this time variation behavior of the domestic risk-return relationship is importantly not the primary aim of this paper, which focuses on testing for the *existence* of such a relationship with regards to the returns to risks over the *full sample*.

6.4.2 Additional CAPM Econometric Specification

As an additional check on the estimated price coefficients, and to investigate the claim by Scruggs that the simple CAPM model will provide biased estimates of the price of risk if the true model of domestic risk is given by equation (6.04), this chapter will estimate that standard simple CAPM in addition to the main study of the ICAPM. For domestic equity

returns the econometric specification of the one factor CAPM, where the only risk factor investigated and priced is the domestic variance, is given by restricting all foreign variables in the ICAPM model to zero, i.e. imposing coefficients of zero on all the variables denoted by the L subscripts in equations (6.06) to (6.10), including the covariance term. This will modify the equations of section 6.4.1 into a CAPM model estimated according to a standard GARCH(1,1)-in-Mean specification.

Scruggs shows³⁴ that, if the risk-return model outlined in equation (6.03) above is the true model of domestic risk and equation (6.02) is estimated instead, then the estimated value of Lambda according to equation (6.02) will overstate the returns to domestic risk as the returns to covariance risk are loaded onto the domestic variance risk parameter.

6.4.3 Data and Estimation Procedure

As in the previous chapter the JSE/Actuaries All Share 40 Top Companies Index (ALSI40) and the Financial Times-Stock Exchange 100 Share Index (FTSE 100) acted as proxies for the domestic and international market portfolio, respectively. The daily closing levels were transformed into daily returns in the standard way as the natural logarithm of the ratio of the consecutive daily closing levels. The annual return on respective 90-day (3 month) Treasury bills, used as the proxies for the risk-free return in each country, were transformed into nominal daily rates for estimation purposes. The study period runs from the usual 01/01/1996 to 31/12/2004, for 2351 observations over the full nine years. To aid interpretation the base used throughout for all the series was a percentage change, with a displayed unit of 1.00 equal to a 1% daily return. Table 13, overleaf, provides some of the important summary statistics for these series.

³⁴ Bias amount between CAPM and ICAPM:

$$\lambda_{CAPM} - \lambda_{ICAPM} = \kappa_{Cov} \left[\frac{\text{cov}(r_J, r_L)}{\text{var}(r_J)} \right]$$

As the values for Kappa, domestic variance and the domestic/international return covariance are in practice all positive, equation (6.02) of the CAPM will overstate the value of Lambda if equation (6.03) of the ICAPM is the true specification.

Table 13: Summary Statistics for Daily Returns on the JSE and LSE

	SA Return	UK Return	SA Risk Free	UK Risk Free	SA Equity Premium	UK Equity Premium
Daily Mean	0,042	0,018	0,033	0,014	0,009	0,003
Daily Std Dev.	1,201	1,161	0,008	0,003	1,202	1,161
Maximum	7,536	6,080	0,050	0,023	7,500	6,067
Minimum	-11,863	-5,175	0,020	0,003	-11,899	-5,728

Notes:

The Equity Premia are defined as the 'Returns' less the 'Risk Free'.

Daily data, sample period 01/01/1996 to 31/12/2004, for a total of 2 351 observations.

While Table 13 is largely self-explanatory, a few characteristics are noteworthy. Firstly, it is clear that equity returns are higher than the risk free returns over the sample period, which is as expected: being riskier, equities should pay a higher return than government chapter. Note the extremely large difference of risk, as measures by the variance of the returns, between the risk-free and the equity returns. The JSE returns are also slightly more risky than the equities on the LSE, and consequently pay higher returns.

Of consequence to the estimation, the domestic equity returns experienced a few extremely large price movements well in excess of the usual return movements to an extent that with their inclusion the algorithm is unable to find convergence. These will be considered outliers for the purpose of this study, as their very nature negates their ability to provide insight into the general behavior of the domestic risk return relationship. Specifically, absolute price movements greater than 6% are judged³⁵ to be magnitudes so different from the rest of the sample that it is possible that they come from a completely different population. To allow convergence and provide a clearer picture to the underlying domestic risk-return relationship the effects of these outliers are loaded onto an outlier dummy. (See equation (6.06)). There are no comparable outliers amongst the LSE returns.

³⁵ The choice of this cut-off magnitude is, admittedly, both subjective and arbitrary. The choice was guided by the principle of selecting the largest magnitude that allowed for convergence to a solution in order to minimise the number of excluded observations. In total, only 7 observations out of 2 351 (0.003%) were excluded.

A final point has to do with the effect the exchange rate has on the risk-return relationship because of the international diversification risk. The accommodation of these exchange rate movements would appear to be vital as the large fluctuations over the period under review are likely to have often swamped the return on the equity markets. However, closer inspection of this shows it to be inappropriate from the market's position to accommodate the exchange rate effect. Specifically, the random walk nature of the exchange rate entails that the best expectation of the day ahead exchange rate level from an investors perspective is today's exchange rate level, i.e. an expectation of zero appreciation or depreciation. Given that, the market would not take account of the random exchange rate movements as, from their perspective, the zero-expected change makes them are unimportant (or, at least, un-actionable) from a day-to-day perspective. Changing the returns on the LSE and the JSE into the same currency for comparison sake would therefore be inappropriate as that ex-post information is not known by the market when it makes the risk-return decision. Essentially, this exclusion of the exchange rate effect in this chapter hinges on two understandings: (i) that the effect of the exchange rate on the JSE that it known so far (such as the previous days' movement) is already priced into the JSE and (ii) that subsequent exchange rate changes are both random and have a day ahead expectation of zero change.

In terms of estimation technique the ICAPM equations (6.06) through (6.10) were simultaneously estimated via Maximum Likelihood using the Marquardt algorithm, with the coefficient values from the initial OLS estimations employed as the starting values for the algorithm. For the simple CAPM, the model was estimated using the same procedure along with the imposition of the zero restrictions on the foreign variables as discussed above.

6.5 Results

Table 14, overleaf, presents the results of the simultaneous estimation of the ICAPM model and CAPM model.

Table 14: The Price of Risk on the JSE: ICAPM and CAPM Estimations

ICAPM				CAPM		
First Moments:				First Moment:		
$r_{j,t} = \lambda_j h_{j,t} + \kappa_j \text{cov}_{jL,t} + \tau_j \text{out} + \varepsilon_{j,t}$				$r_{j,t} = \lambda_j h_{j,t} + \tau_j \text{out} + \varepsilon_{j,t}$		
$r_{L,t} = \lambda_L h_{L,t} + \varepsilon_{L,t}$						
Second Moments:				Second Moment:		
$h_{j,t} = \omega_1 + \beta_1 h_{j,t-1} + \rho_1 h_{L,t} + \alpha_1 \varepsilon_{j,t-1}^2$				$h_{j,t} = \omega_1 + \beta_1 h_{j,t-1} + \alpha_1 \varepsilon_{j,t-1}^2$		
$h_{L,t} = \omega_2 + \beta_2 h_{L,t-1} + \alpha_2 \varepsilon_{L,t-1}^2$						
$\text{cov}_{jL,t} = \omega_3 + \beta_3 \text{cov}_{jL,t-1} + \alpha_3 \varepsilon_{j,t-1} \varepsilon_{L,t-1}$						
ICAPM Model				CAPM Model		
Panel A: Conditional First Moment(s)						
	<i>Coefficient</i>	<i>Std Error</i>	<i>p-Value</i>	<i>Coefficient</i>	<i>Std Error</i>	<i>p-Value</i>
λ_1	0,0279	0,0001	0,0000	0,0455	0,01807	0,0117
λ_2	0,0565	0,0320	0,0780	-	-	-
κ_1	0,0111	0,0003	0,0000	-	-	-
Panel B: Conditional Second Moments						
	<i>Coefficient</i>	<i>Std Error</i>	<i>p-Value</i>	<i>Coefficient</i>	<i>Std Error</i>	<i>p-Value</i>
ω_1	0,0008	0,0002	0,0000	0,0206	0,0038	0,0000
ω_2	0,0032	0,0320	0,0790	-	-	-
ω_3	0,0001	0,0003	0,0000	-	-	-
β_1	0,8202	0,0000	0,0000	0,9009	0,0071	0,0000
β_2	0,9131	0,0320	0,0780	-	-	-
β_3	0,8845	0,0003	0,0000	-	-	-
ρ_1	0,0287	0,0000	0,0000	-	-	-
α_1	0,1146	0,0320	0,0780	0,0860	0,0071	0,0000
α_2	0,0701	0,0003	0,0000	-	-	-
α_3	0,0635	0,0000	0,0000	-	-	-
<i>Log- Likelihood</i>	-6584.34			-3498.05		
<i>Pseudo R²</i>	0,0189			0,0049		

Notes:

Daily data, sample period 01/01/1996 to 31/12/2004, for a total of 2 351 observations.

A dash (-)denotes that the parameter was not estimated for that model.

Pseudo R²'s are computed as the ratio of the sum of squared fitted values and the sum of the squared excess returns

6.5.1 Return to Risks

As can be seen in Table 14, the domestic coefficients for the price of domestic risk and covariance risk are all positive and highly significant, implying that the JSE impounds the information concerning both types of risk. The estimated daily price of domestic equity risk on the JSE is an increase in returns of 0,0279% (EAR: 7,28%) for each single unit increase in volatility. Thus, for accepting the risk of an equity investment corresponding to level of uncertainty where the actual could be 1% above or below the expected return for the following trading day an investor gains an extra 0,03% return. The estimated daily price of covariance risk on the JSE is 0,0111% (EAR: 2,83%) for every one unit of covariance risk between domestic returns and the returns on the LSE, with similar per risk unit interpretations

as for the variance risk price. The domestic equity market therefore appears to price in both types of risks. Given the relative magnitudes of the two risks, the domestic equity market views the uncertainty regarding the return on domestic equities higher than the uncertainty regarding the potential diversification benefits. The representative investor on the JSE appears to be more concerned with domestic returns than international diversification, which is as expected given that domestic investors hold most³⁶ of the JSE ALSI40.

The estimated price of domestic risk according to the simple CAPM model is 0,0455% (12,29%). That this value is higher and slightly less significant than the value estimated according to the ICAPM supports the assertion of Scruggs (1998) that the simple CAPM is a misspecification of the domestic returns to risk, and that the ICAPM with the included covariance risk is a better specification. This is a potentially important finding for much of the domestic studies using the standard CAPM as the pricing specification, as their results could be potential biased through under specification. The calculated Pseudo R^2 's further support this notion that the ICAPM model is a better specification of domestic equity risk-return behavior.

For the LSE, the respective price of domestic risk is estimated at 0,0565% (15,49%). While this coefficient is positive, it is only significant at the 10% level, echoing the mixed literature of such an estimated risk-return relationship under one-factor CAPM models. It is also larger than that for the JSE, though it is likely that this CAPM model is underspecified and the Lambda value biased, so this relatively higher risk price should not be considered a robust result.

³⁶ No actual data is collected by the JSE on the foreign ownership of the ALSI40, though it is plausible to assume that it is not greater than the domestic ownership. (Source: Private correspondence with JSE research department).

6.5.2 Variance and Covariance Specification

As is expected from chapter 3 the coefficients for the GARCH(1,1) specification of the variance terms for both markets and in both models are all significant, and are of the usual sign and magnitudes³⁷. Crucially, the variance coefficients satisfy the twin conditions of non-negativity and covariance stationarity³⁸. For the covariance specification, the significant positive coefficient of the last term is as it should logically be: large movements by the two respective indices in the same direction leads to increased covariance. Movements in opposite directions imply decreased covariance.

The spillover coefficient in the ICAPM model, ρ , is both significant and positive. In line with the literature, this chapter finds that increased volatility on the international market is associated with increased volatility on the domestic market. Note that this figure differs in magnitude, but not direction, from the spillover term isolated in chapter 5, above. This is driven by the use of incomparable methods, specifically with regards to the mean specifications. In this chapter, the specification of the mean was driven by the investigation into the price of risk, whereas in chapter 3 it was driven by the need to correctly isolate the spillover term. As such, the isolation specific methodology specifications of chapter 5 means that that the international relationship isolated there must be obviously be considered the authoritative source regarding the spillover effect, and not the one found in this chapter. The spillover term is included here merely as increases in foreign volatility lead to increases in domestic volatility and accommodating for that fact better models the domestic volatility process.

37 Daily Half Lives by equation: Eq.(6.06): 10,2 days; Eq.(6.07): 40,9 days; Eq.(6.08): 12,9 days, Eq.(6.10): 52,5 days. Half-lives, i , were found as before by solving $(\alpha_i + \beta_i)_i = 0,5$. Note that these differ from chapter 3 due to different mean specifications.

38 Covariance stationarity exists only if: $\alpha_i + \beta_i < 1$

6.5.3 Market Segmentation and the Gains from Diversification

While admittedly a broad brush, the significant effect that domestic risk has in the ICAPM model leads to the suggestion that the domestic market is to some degree segmented from the international market, as domestic information contains significant market information regarding domestic equities that is not contained in the international market risk information. Indeed, the large difference in relative risk prices amongst domestic equities implies that this segmentation is quite substantial. This finding corresponds to that of chapter 5, which found that most of the domestic price determination is driven by domestic factors.

Through international diversification, investors can gain the same return for lower volatility, or, correspondingly, higher returns for the same volatility. Employing the estimated value for κ_{cov} with equation (6.05) and solving out for the full series, it is also possible to get a measure of this gain from having an internationally diversified equity portfolio following De Santis and Gerard (1997). While the measure exhibits significant time-variation given the interaction of the time-varying variances and covariances, for the same level of volatility as the domestic market portfolio the expected average daily gain from an internationally diversified portfolio over the full sample is 0,0238% per day. As the mean daily return over the risk free rate in South Africa over this period of 0,0074%, this is a substantial expected benefit. It is interesting to note that the 6,285% effective annual rate of this benefit is far higher than found by De Santis and Gerard (1997) for the US market (2,11%), implying that domestic investors have more to gain from international diversification than investors with large home markets. This result of significantly larger returns to international diversification for investors with small home markets is also found by Nilsson (2002), who finds effective annual diversification returns for the smaller markets of France, UK and Switzerland ranging from 4,46% to 9,60%, and far smaller effective annual returns of 0,73% to 0,98% for the US and Japanese markets.

6.6 The Risk Return on the JSE Conclusion

This chapter estimated a two-factor ICAPM model using a parsimonious bivariate GARCH(1,1)-M model that incorporated international volatility spillovers to estimate the price of domestic (variance) and international diversification (covariance) risk on the JSE. Using the LSE as the proxy for the international equity market, this chapter found a number of results regarding risk and return on the JSE.

Firstly, and most importantly, this chapter found significant evidence that the domestic equity market rewards risk taking; that the fundamental relationship between risk and reward exists amongst South African equities. The representative domestic investor on the JSE receives higher returns for investing in equities when they have higher risks associated with them.

Specifically, the chapter found that the daily return to domestic equity risk was 0,0279% for every one unit increase in risk. The JSE rewards investors who hold equities when there is greater uncertainty around the expected return of such equities. As the average mean daily equity premium (the equity return less risk free return) over the sample is 0,007%, this return to risk is quite a substantial relative return on risk.

The chapter also found evidence that the domestic market rewards the risk due to decreases in the diversification property. The reward to the representative investors for diversification risk is an expected increase in daily returns of 0,0111% for every one-unit decrease in diversification benefits.

With regards to the relative domestic significance of the risks, for the representative local investor the risk associated with the variance of domestic returns is far more important than the risk associated with international diversification risk, with variance risk being priced in at almost three times the amount that covariance risk is priced in. This is a largely expected

result given that the representative investor on the JSE is likely to be more concerned with the gains from domestic returns than with the benefits of international diversification.

Corresponding to the previous chapter, evidence is found that the JSE is imperfectly integrated with the world equity market. Information concerning the domestic equity market provides additional significant information concerning domestic returns above and beyond that provided by the international market risk.

Having an internationally diversified portfolio exposes domestic equity investors to lower risks for the same return, or conversely, higher returns for the same risk. This study found that this international diversification premium is quite substantial, with domestic investors able to earn an expected 6,285% additional effective annual return for an international portfolio with the same variance (risk) as a domestic portfolio.

Lastly, this chapter found that the simple CAPM asset-pricing model, whereby the variance of the market portfolio is the sole determinant of the equity return premium, ignores important risk on the JSE. This will bias the return to domestic risk upwards as information concerning covariance risk is loaded onto that parameter in the absence of a separate specification.

CONCLUSION AND INVESTOR INSIGHTS

7 CONCLUSION

This thesis investigated the behavior of the risks and returns on the JSE within an international context. It was broadly structured into two related parts. The initial focus was on domestic risk and return behavior in isolation. The subsequent focus concerned these risks and returns from an internationalized perspective, using the knowledge gained from the initial section. Specifically, chapters 2 and 3 focused on the persistence and econometric modeling of domestic returns and risks, respectively. As the investment process is necessarily forward looking, chapter 4 furthered this investigation by looking the econometric forecasting of these risks and returns. Chapters 5 and 6 then presented the main study of this thesis by examining these risks and returns from an internationalized equity market perspective. Chapter 5 investigated the relationship between, on the one hand, domestic returns and international returns, and, on the other hand, domestic risks and international risks. Chapter 6 then focused on the domestic risk-return relationship within this international context.

In concluding this study, a major attraction of this type of study is that its results need not be read in a theoretical vacuum. The focus on domestic equity market behavior allows its results to generate practical insights for investors. As such, the next and final section presents the information drawn from this study that would be of practical interest to investors on the JSE³⁹.

³⁹ It is important to remember that these results are strictly true only for the period under review, and should be interpreted as such.

7.1 Practical Insights for Investors

It appears South African equity returns and risks have very different levels of persistence. The existing literature and the empirics from chapter 2 suggest that the JSE is likely to be weak market efficient, having no persistence (or memory) in its returns. In contrast, domestic equity volatility displays significant degrees of persistence. In general, periods of high (low) variance follow periods of similar high variance, and periods of low variance follow periods of similar low variance. From an investors' perspective, this suggests that it is possible to (partly) gauge tomorrow's variance or covariance between the markets based on today's variance or covariance between the markets. It also implies that investors can use the ARCH class of models to model domestic volatility⁴⁰.

Specifically, the revealed short memory structure of domestic risks leads to the recommendation that a 1,1 ARCH class structure will be an appropriate specification of domestic volatility for investors to use. The application of the GARCH(1,1) model, for example, appears to adequately model the persistence amongst the excess returns. Investors should also note that, because of the existence of the leverage effect, negative returns on the JSE today will lead, in general, to higher volatility tomorrow than if there was a positive return of the same magnitude.

This persistence of volatility on the JSE, in contrast to that of returns, allows its risks to be partly forecastable. If investors would like to forecast tomorrow's volatility the TARCH(2,2) specification provides the best unbiased forecast, and if they are looking to forecast volatility over the coming week then the EGARCH(1,1) forecast is preferred. However, it must be remembered that this one week ahead forecast might be too low. Generally speaking, one day ahead volatility forecasts on the JSE are likely to be unbiased estimators of the actual volatility on the JSE, while one week ahead forecasts are likely to have a systematic bias. The amount of volatility that can be forecast is also quite low, with the forecasts never able to forecast at most half (and usually far less) of domestic volatility, especially for a one day

⁴⁰ Note that this result, as with all the results in the thesis, were derived using parametric tools. The examination of these results using non-parametric techniques is a potential area of future research.

ahead forecast. Investors should also be aware that the South African market typically over-forecasts volatility, and often the use of standard econometric or statistical methods will provide a better guide. In this light, this study found that a five day moving average provides a reasonable, easy to construct guide for investors to use as a forecast of future volatility on the JSE, at least for a one day ahead forecast. In addition, as a potential future research area it would be interesting to see how accurate alternative non-ARCH models such as a Bayesian Vector Autoregression (BVAR) or models that include equity fundamentals (for e.g. P/E or leverage ratios) forecast the volatility.

Investors can confidently take prudent risks on the domestic market in the confidence that, in general, the domestic market rewards this risk taking. Research presented in this thesis shows that taking on equities that have higher risk(s) attached to them generally leads to higher risks. The premium on this risk is also relatively large. The domestic market rewards not only the traditional equity risk of increased future volatility, but also prices in the risks surrounding international diversification.

Investors should consider the future behavior of the foreign equity market as part of their investment analysis, as domestic price movements and volatility are strongly associated with their international equity market counterparts. Equity asset price increases (decreases) in the international equity market are associated with increases (decreases) in domestic equity asset prices. Increased (decreased) volatility in the international equity market is associated with increased (decreased) domestic equity market volatility. Therefore, in making investment decisions, domestic investors should incorporate information regarding the international equity market into their views of the domestic equity market. For instance, if the outlook for the international equity market suggests that there may be increased volatility over the coming period(s), then investors should understand that this same information suggests that the domestic equity market may be more volatile over the coming period(s). Additionally, if the international market is viewed as being overvalued and in need of a correction, i.e. a price decrease is generally expected, then in general this information implies that long positions in domestic equities should possibly be avoided. While many of these beliefs are already held by the market, this study provides a rigorous formal defense for them.

Investors should also note that, using daily data, this thesis found that the associations between the domestic and international market is chiefly through the same, concurrent trading period. Investors therefore cannot use today's behavior of the foreign equity market to infer information regarding the movement of the local market over tomorrow's trading period. However, that domestic returns and volatility are associated internationally, that they share some common information source, provides an avenue for potentially profitable future research. Using higher frequency data, such as hourly but more likely per minute or tick data, potentially excess returns generating information could be found regarding lagged spillover effects. However, caution must be exercised given the nature of such idiosyncratic high frequency data. It is likely than any lagged pattern that is found will be transient and unstable, and inferring information from such messy and extremely noisy data means that trading based on such research much be considered relatively risky.

However, even with the daily associations this research found investors should not be too focused on international market moves. Due to the international segmentation of the domestic market, domestic conditions play the dominant role in determining the movements in domestic equity assets. The broad ALSI40 index overall has only a fifth of its movements explained by foreign equity market behavior, and the remaining four-fifths by domestic factors. While this changes yearly, ranging from a third (in 1998) to a tenth (in 1996), domestic information is always more important than international information, with the consequent domestic focus to forward looking investment research.

This relative importance, and therefore focus by investors, of foreign information versus domestic information also differs by sector. Investors in the Cyclical Consumer Goods sector should focus the least on international equity market, as more than 95% of the movement in this sector is domestic information. In contrast, investors in the Financials sector should be the most concerned with international equity market behavior, which explains approximately a fifth of the total movement in the Financials sector behavior.

It is desirable for domestic investors to have an internationally diversified portfolio. Doing so exposes South African equity investors to lower risks for the same return, or conversely, higher returns for the same risk. This international diversification premium is quite substantial. For an international portfolio with the same variance (risk) as a domestic portfolio, domestic investors were able to earn an expected 6% additional effective annual return over the sample under review.

Investors must be weary when basing decisions on research conducted using the popular and (widely used domestically) CAPM asset-pricing model. South Africa's open equity market means that the estimated and much employed Betas generated from such CAPM analysis are likely to be biased upwards as information concerning covariance risk is loaded onto that parameter in the absence of a separate specification. The estimated returns for an investor holding a portfolio based on such CAPM research are therefore likely to be lower than he/she expects a-priori.

[...The End...]

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APPENDIX

A1: Component ARCH

As a graphical aid in understanding the Component ARCH's two components of volatility persistence consider Figure 3, below.

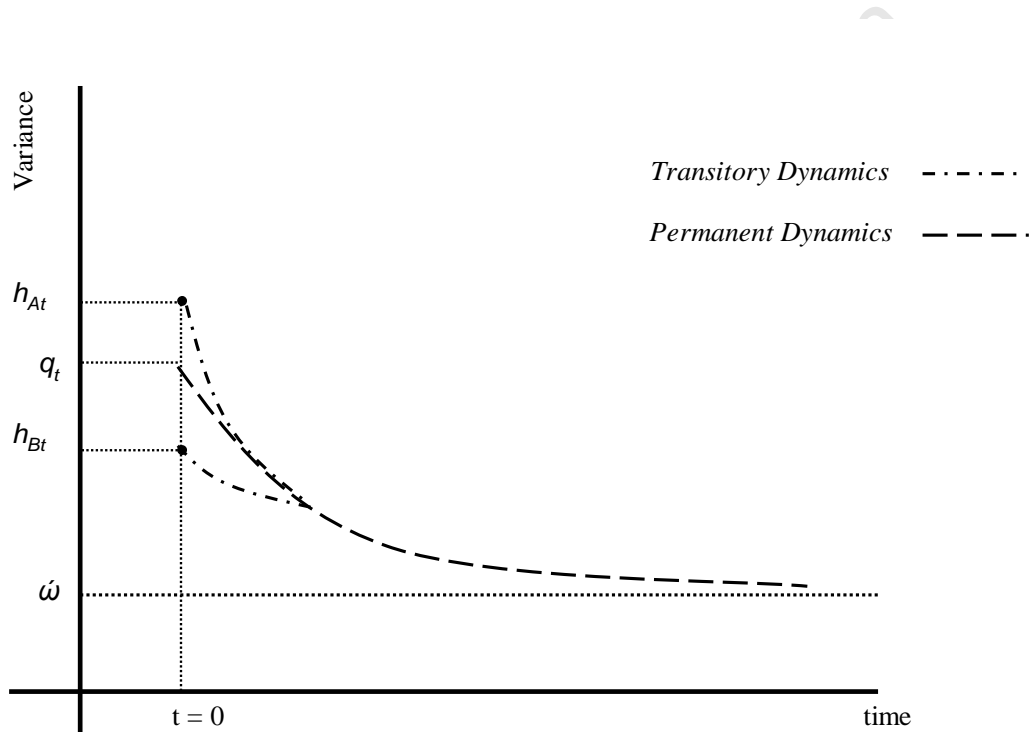


Figure 3: Permanent and Transitory Components of Volatility Persistence

Consider an excess return at time $t=0$ in figure 1 that has a variance of the magnitude h_{At} . Assume for clarity sake that before the return the variance level was the long-run time-invariable 'underlying' value ω , and there are no subsequent returns. There are two different dynamics whereby this magnitude of squared returns at time $t=0$ continues to impact on the

future variance, the Permanent dynamics over the long-run and Transitory dynamics over the short-run.

With the Permanent dynamics the influence of this excess return of magnitude h_{At} declines slowly over the long-run towards zero (the dashed line). When this has happened, when this return no longer influences the future variance, the equities again have the ‘underlying’ value of variance ω .

The Component ARCH proposes that, in addition to this long-run trend rate of decline, the effect of the returns declines faster (slower) if it is above (below) the time-variable mean magnitude of volatility q_t (as per the Permanent Component). In other words, there are two dynamics acting on the returns decline at any one time, the long- and short-run. The short-run dynamic describes how the difference between the current return and the long-run trend declines very quickly. In the figure, the short-run dynamic causes the return above q_t , e.g. h_{At} , to decline very quickly downwards towards q_t . Combined with the long-run decline dynamic, the influence of the return declines initially relatively fast along the short-run path (the dotted and dashed path), and then slows to the decline rate of the long-run path (the dashed line) once the difference between the returns’ influence and the long-run time-variable mean has disappeared. For a return with a magnitude of less than q_t , h_{Bt} , the influence declines at a slower rate along the short-run path (the dotted and dashed path) and then increases to the decline rate of the long-run dynamic once the difference between the returns’ influence and the long-run time-variable mean has disappeared. This is because the short-run dynamic attempts to close the difference between the current return and the much higher long-run time-invariable mean, q_t . This combination of long-run decline and short-run increase in influence leads to the return declining slowly initially and then declining faster once it reaches q_t .

A2: Volatility Forecast Graphs

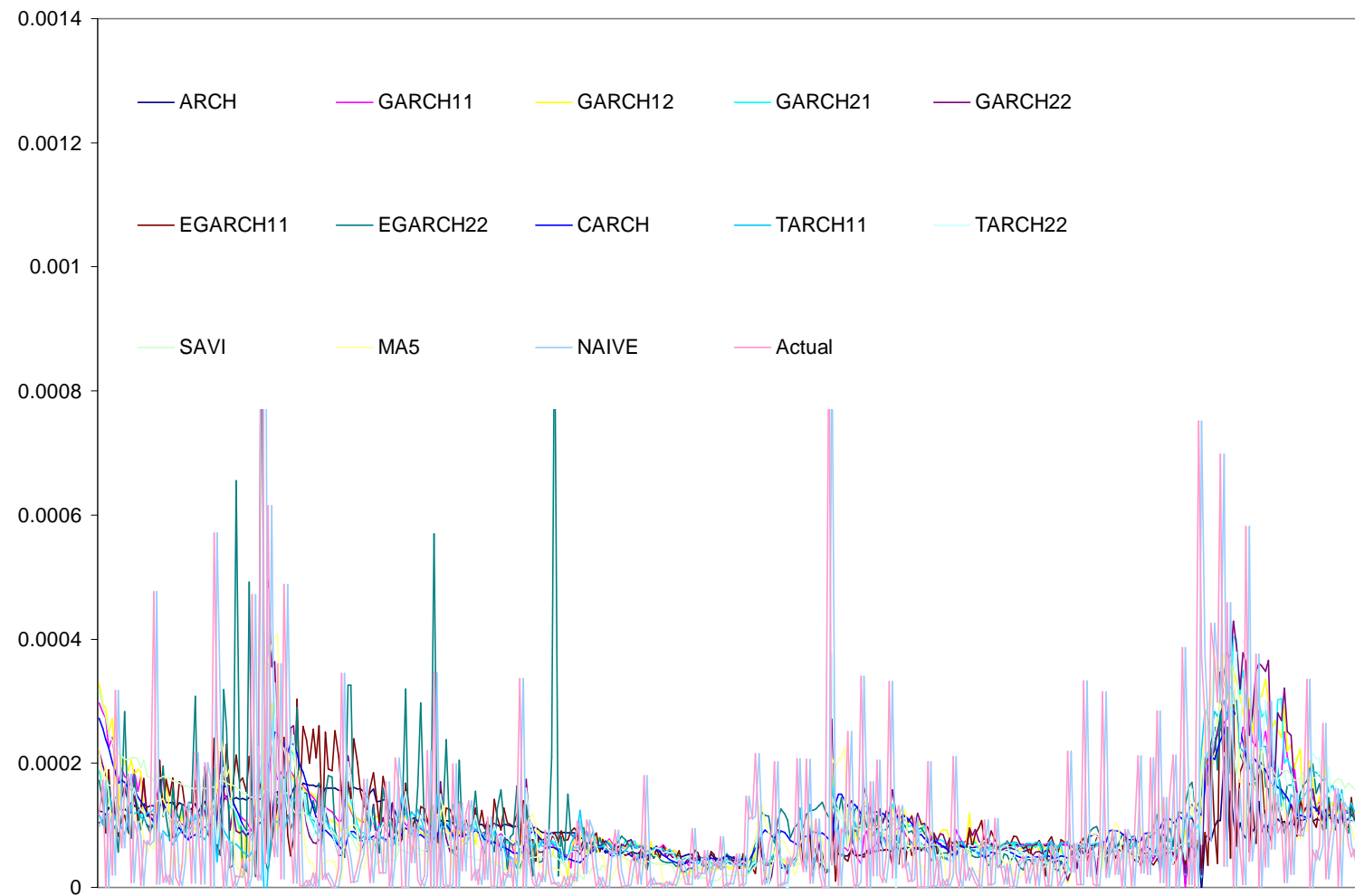


Figure 4: Day Ahead Volatility Forecast

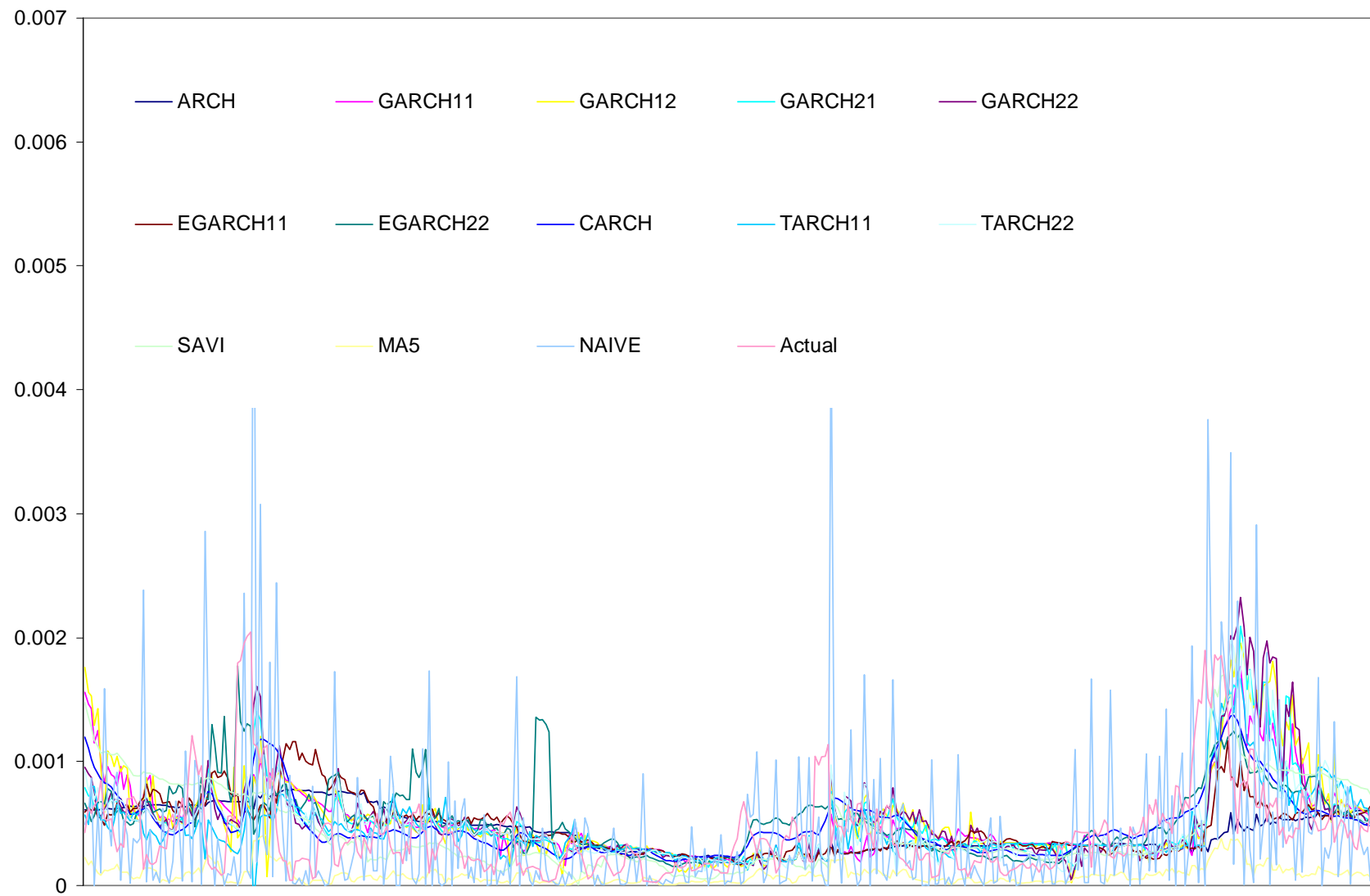


Figure 5: Week Ahead Volatility Forecast